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F. Kerseboom p. *From an Original in the possession of D.r Meade.* *G. Vertue Sculp. 1738.*

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THE

Philoſophical Works

Of the HONOURABLE

ROBERT BOYLE Eſq;

Abridged, methodized, and diſpoſed under the GENERAL HEADS

OF

PHYSICS,
STATICS,
PNEUMATICS,
} NATURAL HISTORY,
CHYMISTRY, and
MEDICINE.

The whole illuſtrated with NOTES, containing the *Improvements* made in the ſeveral *Parts* of natural and experimental *Knowledge* ſince his time.

In THREE VOLUMES.

By *PETER SHAW*, M. D.

THE SECOND EDITION, CORRECTED.

LONDON:

Printed for W. INNYS and R. MANBY, at the *Weſt-End* of St. *Paul's*; and T. LONGMAN, in *Pater-Noſter-Row*.

M. DCC. XXXVIII.

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TO

The Right Honourable the

LORD *BURLINGTON.*

MY LORD,

THE original philoſophical writings of the Honourable Mr. *Boyle*, are a treaſure worthy the cabinets of princes; and, perhaps, the moſt valuable preſent of that kind the world ever received. If my ſucceſs in abridging them be anſwerable to my wiſhes, and the pains beſtowed in the attempt, I preſume they will not, in this form, diſhonour their noble author; nor prove unworthy the countenance and acceptance of your Lordſhip. At leaſt I perſuade my ſelf it were injurious not to addreſs the work to the noble family of the *Boyles*, whereto the ties of nature, as well as affinity of genius, taſte, and other qualifications ſhared in common with the great author, direct me.

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May it, therefore, pleaſe your Lordſhip, to permit this firſt Volume of the Abridgment to bear your Lordſhip's name; whereby freſh honour will be derived to the noble author of the originals; and, in return, your Lordſhip's character be ſet in open view; ſince the works of Mr. *Boyle* confeſs the genius, taſte, and temper ſo happily united in your Lordſhip.

I am,

MY LORD,

Your Lordſhip's moſt humble,

moſt obedient,

And moſt devoted Servant,

Peter Shaw.

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A GENERAL

PREFACE

TO THE

Abridgment of Mr. *BOYLE*'s

Philoſophical WORKS.

THE philoſophical writings of Mr. Boyle *have, from their firſt appearing in public, done an honour to his country, and procured him a general eſteem in the world. The novelty, the variety, the dignity, and the uſefulneſs of the ſeveral ſubjects he treats, with the eaſy and familiar manner wherein they are handled, recommend his performances to the whole body of mankind: Mr.* Boyle *accommodates himſelf as well to the unlearned and the novice, as to the philoſopher and the ſcholar; his whole ſcope and deſign being, with the utmoſt candour and ſimplicity, to communicate thoſe numerous and important diſcoveries, which coſt him infinite pains and application to make.*

On the other hand, as Mr. Boyle *was the introducer, or, at leaſt, the great reſtorer of mechanical philoſophy among us, ſo, by endeavouring to deliver himſelf in the moſt full and circumſtantial manner about it, he has ſpun out his works to what, now that philoſophy is more generally known, appears an immo-*

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derate length. His numerous pieces too being all publiſhed occaſionally, and in a miſcellaneous manner, 'tis a matter of ſome difficulty to reduce them to an order fit for a ready and commodious peruſal. Whence it is, that few having been at the pains to collect, methodize, and regularly ſtudy his excellent writings as they require, the value ſet upon them, though great indeed and general, falls vaſtly ſhort of what they merit; proceeding rather from the report of here and there a diligent man, than from any perſonal and actual knowledge, that the generality, even of philoſophers, had of them. But thoſe who have been moſt converſant with Mr. Boyle, *agree, that no author deſerves better of mankind, or merits to be more generally read, than he. And, in order to procure him this general peruſal, as nothing ſeemed more conducive than to digeſt and contract his works, into a juſt and regular abridgment, I was requeſted to attempt one. For, notwithſtanding the* Epitome *of Mr.* Boulton, *a well digeſted, and compendious collection of all Mr.* Boyle's *philoſophical writings, has been generally wiſh'd for, and declared, by unexceptionable judges, to be greatly wanting. 'Twas the opinion of ſuch that principally determined me to the undertaking; and I ſhall think my labour well beſtowed, to have acquitted myſelf in it with their approbation.*

The deſign of an abridgment, I conceive, is clearly to exhibit the whole ſubſtance of an author, without admitting any thing ſuperfluous.

How far I have anſwered this end, in abridging the philoſophical works of Mr. Boyle, *is not for me to determine. It will be expected, however, that I give ſome account of my proceedure herein.*

Mr. Boyle's *philoſophical writings appearing to be a miſcellany of eſſays, upon a great variety of ſubjects, it was judg'd convenient, in the firſt place, ſeverally to reduce them under the reſpective general heads whereto they naturally belong'd; whence the ſcope and deſign of each ſeparate piece, might preſently become conſpicuous; and the ſenſe and tendency of the whole, thus rang'd, be the better judg'd of.*

A farther advantage, I preſumed, muſt accrue from placing them in ſuch a manner, that thoſe which were introductory or fundamental,

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fundamental, might ſtand firſt, and prepare the way for the reſt; and that all might naturally follow, mutually illuſtrate, and, as much as poſſible, prove, confirm, and lead to each other. To this end, likewiſe, it was found abſolutely neceſſary to rectify numerous diſlocations; to bring all Addenda *and inſertions into their proper places; and ſo to diſpoſe and marſhal the ſeveral ſcattered articles relating to the ſame ſubject, that they ſhould together tend to compoſe one regular whole. But as Mr.* Boyle *never deſigned to write a body of philoſophy, only to beſtow occaſional eſſays on thoſe ſubjects whereto his genius or inclination led him; 'tis not to be expected, that even the moſt exquiſite arrangement, ſhould ever reduce them to a methodical and uniform ſyſtem, tho' they afford abundant materials for one.*

In the next place, obſerving that Mr. Boyle's *manner was, ceremoniouſly to addreſs particular pieces to particular perſons; to uſe large preparatory diſcourſes, before he entred upon his deſign; and always to write in a copious, diffuſive, and circumſtantial ſtile; I determined to leave out in the abridgment whatever was merely perſonal, or had no relation to the argument; and to contract his words into as ſmall a compaſs as appear'd conſiſtent with the perſpicuity requiſite in philoſophical writings. And I ſhould be ſorry that any perſon, tho' a ſtranger to Mr.* Boyle's *diſcoveries, or the modern philoſophy, ſhould not, by the proper application, fully underſtand his doctrine in the abridgment; or not be enabled by it to go through all his experiments, proceſſes, and operations, in the very manner wherein himſelf delivers them.*

And becauſe ſome exceptions have been taken to Mr. Boyle's *originals, on account of the paſſages that frequently occur in different languages from that wherein he wrote, and the quaint, antiquated, or uncouth expreſſions he ſometimes uſes; it ſeem'd convenient to make him wholly* Engliſh; *to throw out the harſher words and phraſes; and ſo far to alter the ſtyle, that it ſhould not offend a merely philoſophical ear: and to do more, in this reſpect, was deemed an unneceſſary labour. For, as I was all along to preſerve the ſenſe of the author pure from any foreign turn or tincture, it ſeemed moſt expedient to employ his very words, wherever they appeared conciſe, expreſſive, and unexceptionable.*

And theſe are the views I had, with regard to the author, in this undertaking.

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Having now reduced Mr. Boyle's *philoſophical works under diſtinct general heads, I judg'd it would be acceptable, if to each were prefix'd ſome ſhort account of the doctrine rang'd under it; that the reader might come a little prepared to the conſideration thereof.*

And to render this abridgment the more uſeful and ſatisfactory, it was judged requiſite to add, by way of notes, the later diſcoveries and improvements, in the principal ſubjects treated of by Mr. Boyle. *'Twas far from my deſign in this, to write a comment upon the author; that were a work for ſome great maſter in natural and experimental knowledge. Conſcious of my own inabilities, I deſigned no more than to transfer from the great Sir* Iſaac Newton, *and ſome few other eminent and ſucceſsful enquirers into nature, ſuch particulars as tended to illuſtrate, confirm, or improve, the doctrine and diſcoveries of Mr.* Boyle.

What ſtands collected from various pieces of our author, and thrown together by way of general preface to his philoſophical writings, will render it needleſs for me to enter into the particular nature, method, and deſign of them; or to anſwer the objections whereto they may ſeem liable: all this is there done by the author himſelf, in a manner ſuperior to any I pretend to. I ſhall, therefore, only obſerve farther, as to my own part, that I have, thro' the whole courſe of the work, conſulted the advantage of the reader, as well as the reputation of Mr. Boyle.

'Tis an equal regard to both, that here determines me to dwell a little upon the excellencies of the author; and the advantages to be reaped from a peruſal of his works.

Mr. Boyle *takes up his reader at the elements, or fundamental principles of things, and with exquiſite judgment conducts him through all the regions of nature, to furniſh him with objects, whereon to exerciſe his faculties; and, being firſt ſollicitous to make him a general philoſopher, leaves him prepared for any farther enquiry he ſhall think fit to make, into the works of nature or art.*

The beſt and only ſolid foundation for philoſophy, is its uſefulneſs to mankind; and the only way to gain it the reputation it deſerves, muſt be to manifeſt the great advantages that attend

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attend the ſtudy thereof. Mr. Boyle *has been every where careful to ſhew, that nothing can be more ſerviceable and beneficial in life, than experimental philoſophy in general. The Men of wit and learning have, in all ages, buſied themſelves in explaining nature by words; but it is Mr.* Boyle *alone, who has wholly laid himſelf out in ſhewing philoſophy in action. The ſingle point he perpetually keeps in view, is to render his reader not a talkative, or a ſpeculative, but an actual and practical philoſopher. Himſelf ſets the example: he made all the experiments he poſſibly could upon natural bodies, and communicates them with all deſirable candour and fidelity.*

He well knew, that experiments are the life and ſoul of natural knowledge; and that no real improvement can therein be made without them. The framing of notions, and deviſing of ſchemes, may make a notional or ideal philoſopher; but experiments alone, or the dealing with natural bodies, and applying them to each other, can make a real and actual one. Mr. Boyle *has left us ſuch an ample catalogue of trials, in all the parts of natural philoſophy, and ſuch foundations for farther diſcoveries, as can only be fully proſecuted and applied by the* Boyles *and the* Newtons *of future ages.*

To the want of proper experiments, and the taſte for reading and making them, muſt be attributed all our ignorance in natural things. What light has Mr. Boyle *let into the dark parts of nature, barely by means of experiments! The foundation and main ſpring of his whole philoſophy, is the obvious art of experimenting. But he was very far from deviſing and making experiments, in order to confirm or eſtabliſh a ſyſtem, raiſed without the help of them; for in that caſe, 'twas his opinion, the greateſt advantage is loſt, which might otherwiſe attend them. A man wholly poſſeſſed with any one view ſees all things in the light of it; and ſlights whatever, at firſt ſight, appears to have no tendency thereto. Thus the ancient, and ſome modern chymiſts, intent and fixed upon the melioration of metals, or tranſmutation, loſt all the benefits of that infinite number of experiments they made, except what tended to their darling end. But if the mind be kept entirely open and diſengaged, every phenomenon will be obſerved. And this was*

Mr.

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Mr. Boyle's *manner of proceeding. Nay, after he had gone the greateſt lengths he was able, he draws no dogmatical concluſions from his premiſes; well knowing, that the great diſcoveries ſtill remaining to be made, may happen to claſh with, or over-turn any ſyſtem, that, for want of light, might once appear rational and well founded. The generality of mankind are in poſt-haſte to draw concluſions, before they have conſidered the premiſes; and uſually determine off-hand upon a ſubject: but* Mr. Boyle, *after having well pondered his experiments and obſervations, and view'd them on all ſides, with their ſeveral circumſtances, is exceeding cautious in reaſoning from them. He never raiſes an hypotheſis to ſolve phenomena; but if the ſolution does not of itſelf grow out of them, when attentively conſidered, he leaves all as he found it; and waits for further diſcoveries to inform him. This practice, as it commands our admiration, on account of its difficulty; ſo it highly deſerves to be imitated, on account of its uſefulneſs.*

The buſineſs of experimenting he reſtrains not to any particular branch of ſcience; but applies it, in full latitude, to all the elements, and all the bodies they mix with, or go to compoſe. The air, earth, fire, and water, all are ſcrutinized and tortured by experiments, to confeſs their natures, offices, uſes, and the wiſdom and deſign of their creation. 'Tis by this means that he ſhews us very various and ſurprizing properties and effects of that familiar fluid, the air or atmoſphere; what numerous broods of effluvia float therein; how different bodies are affected by it, according to their different diſpoſitions; its uſes to the vegetable, animal, and mineral kingdom; how, like an immenſe ocean of a general menſtruum, it acts variouſly upon all the bodies it ſurrounds, as different combinations of effluvia take their turns therein; whence numberleſs, unforeſeen diſorders in the animal œconomy, and ten thouſand effects upon even inanimate bodies, which to vulgar eyes appear aſtoniſhing and unaccountable. 'Tis by this means, that he ſhews and explains, how the vaſt body of the earth is continually ſending out her expirations into the atmoſphere, and feeding vegetables from her ſuperficial parts: whilſt innumerable operations and chymical proceſſes, are carrying on in her entrails; metals forming,

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forming, ſtones growing, minerals mixing, fuming, ſubliming, ſpring, exploding, &c. *Fire, that grand myſtery of nature, he thus brings us acquainted with, whether ſolar, ſtellar, culinary, ſubterraneal, or artificial, by finding out its various effects and operations upon bodies expoſed to it; and ſhews us, that by rareſying their parts, mixing with them, lodging itſelf therein, altering their texture, increaſing their gravity, and giving new modifications to the matter of them, it produces ten thouſand varieties, and all the qualities and operations in natural bodies. The element of water he examines in like manner, deſcribing its properties, effects, and the various forms it may aſſume, in all the different places, as the air, the earth, and even in conſiſtent, or the hardeſt of bodies, wherein 'tis found; tracing it from the clouds and rivers, to the deepeſt ſeas, whoſe productions and concealed treaſures, he, by experiment, lays open. He traces animals of all kinds, from their firſt ſenſible magnitude, to their full growth; and applies his experiments to them in every ſtage; whereby he ſhews us the firſt beginnings and increaſe of life; the ways whereby it may be reſtored, after it ſeems wholly to have left the body; that all living creatures are actual machines, ſo wiſely contrived and ſet together, that their parts ſerve various purpoſes at once, without interfering with one another; that the loſs of limbs in animals, is not abſolutely irreparable; that ſome may long ſurvive the want of their hearts and heads, and even propagate their ſpecies without them. In the vegetable kingdom, he ſhews us the riſe and increaſe of trees and plants from water; the means of forwarding their growth, and making them fruitful; with the ways of preparing, improving, and preſerving their products, and the various liquors they may be brought to afford. And in the mineral kingdom, he inſtructs us how all ſtony, metalline, and terreſtrial bodies are form'd, grow, and ripen; ſhews us the ſteps that nature takes, in the ſeveral proceſſes for their preparation; from what original matter they all ſpring; how gems aſſimilate, concrete, and harden; whence metals, of all kinds, whence the ruby flames, the diamond ſparkles, and gold obtains its lovely qualities. In ſhort, he thus leads his reader thro' all the elements, and all the kingdoms in nature;*

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nature; ſets to view and examines the ſeveral combinations, creatures, and productions of them; their properties, powers, virtues, uſes, ways of working, &c. *and this in the moſt inſtructing and entertaining manner. He ſhews us that we inhabit a much wiſer, and better regulated, a more active and inſtructive world, than is generally ſuppoſed; he makes us obſerve, that all the bodies around us are inceſſantly in action, and their parts in conſtant motion; that nature is perpetually carrying on her own grand ſchemes and deſigns, whether we regard them or not; that even our own bodies are, every moment, acted upon, affected, alter'd, and reſtored, by a vaſt variety of agents, which we little dream of. He does not barely amuſe us with notions and ſpeculations, but lays before us, and makes us ſee the important works of nature, wherein ourſelves, and all we poſſeſs, are nearly intereſted and concern'd. Mr.* Boyle *calls out a thouſand latent qualities in the air; a thouſand uſeful ſubſtances from the bowels of the earth, and the depth of the ſea. He greatly opens and dilates the mind; gives us noble and generous thoughts of nature, and of our own abilities; manifeſts that even deſperate things may be attempted with ſucceſs; and ſhews no quarter to the lazy, indolent temper of thoſe, who, from ſhallow notions, and a want of having ſeen the powers in natural bodies are for diſcouraging all new and grand undertakings; and uniting the knowledge of the philoſopher, with all the freedom and addreſs of the gentleman; he renders the moſt daring projects promiſing and advantagious. He will never allow us to conſider the world as a rude heap of dull, inactive matter; but convinces us, that it is a grand and noble machine, continually actuated, inform'd, and governed by a moſt wiſe and beneficent Being, who keeps all the parts thereof in motion, and makes them act upon one another, according to certain laws; then bringing us acquainted with theſe laws, he enables us to make uſe of the ſame ſtratagems and contrivances, which nature herſelf employs; which, ſurely, are capable of performing the greateſt things, when rightly applied; that is, when applied as Mr.* Boyle, *by his own example and experience, directs us. But he ſhews alſo, that in order to make the moſt advantagious uſe of theſe powers, a general knowledge of nature*

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is required. Without large and comprehenſive views; without being well verſed in mechanical arts, and the ſeveral branches of natural knowledge, ſo as to make one aſſiſting to another, and all, in their turn, conſpire to the ſame end, Mr. Boyle *encourages no man to be a projector.*

He is particularly cautious to guard his reader againſt every operation, that might any way prove dangerous or hurtful; and to prevent his impoſing upon himſelf by any ſuperficial obſervation, any fallacious or contingent experiment, whether made in his own perſon, or delivered by others. So much the more afflicting is it to find, that he ſhould himſelf be charged with having attributed too much to the power of nature and art; and to have eaſily credited uncertain accounts of things uncommon and extraordinary. In this particular I beg leave to diſſent from the general opinion which has crept abroad of Mr. Boyle. *From an attentive peruſal of his admirable writings, I muſt, in juſtice to his memory, declare, that in general, no author appears to have been more inquiſitive into the foundations and evidence of the narratives he receives from others; or to have ſhewn greater ſagacity and induſtry in diſcovering their weak ſides; always frankly propoſing them, as he received them, to be confirmed or overthrown, by farther ſearch, and future diligence. And for proof of this, I appeal to the manner wherein he delivers himſelf, upon what are, or were eſteemed the moſt exceptionable things in his writings: the ſpecific virtue of the* Peruvian *bark, rue-leaved whitlow graſs,* Ens Veneris, Oſteocolla, *the* Ens Primum *of baulm,* Butler's *ſtone, the ſympathetic powder, the weapon ſalve, the alkaheſt of* Paracelſus, *the* virgula divina, *the tranſmutation of metals, projection, or the philoſopher's ſtone,* &c. *and deſire he may herein be compared with the moſt approved and judicious authors, who have treated of the virtues of remedies, the ſecrets in chymiſtry, and the powers of nature. No doubt Mr.* Boyle *may appear to give more into the belief of ſome extraordinary things than the vulgar, or perſons unacquainted with experimental philoſophy, and the immenſe powers and ſtrange operations of nature and art; but the queſtion is, whether he has here gone farther than his evidence carried him.*

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He alſo relates, upon his own knowledge, many things very aſtoniſhing and incredible, to minds unprepared, by philoſophy, to entertain them. But Mr. Boyle *was ſo happy, as to have ſeen, with his own eyes, much more of the powers of nature and art, than can eaſily be imagined. If we conſider the numerous phenomena, which, in a very long ſeries of years, ſpent upon natural enquiries, moſt of them ſucceſsful, muſt have been preſented him, by the proceſſes of his laboratory, the experiments of his pneumatic engine, his mechanical, optical, hydroſtatical, and all other kinds of trials; the correſpondence he happily cultivated with the whole learned world; and particularly with the chymiſts of all nations; the various ſecrets he purpoſely kept to exchange for theirs; and the conſtant practice he made of doing this; we ſhall ſee reaſon enough to perſuade us, that he might well be enabled to deliver things that ſhould ſound odd, ſtrange, and ſhocking to vulgar ears. To render the moſt innocent fluids poiſonous, without altering their colour, taſte, ſmell, or any obvious quality; utterly to eraſe the hand-writing in a ſheet of paper or parchment, without at all unfitting either for ink; to make a baſe metal paſs even upon goldſmiths, for gold; not to mention the more ſurprizing and ſhocking experiments of the like ſtamp; are things that can hardly be thought poſſible, or practicable by the vulgar; yet ſome chymical philoſophers could perform them with eaſe. But there are ſome philoſophers, and even chymiſts, who, if you ſhould tell them that Mr.* Boyle *had a certain liquor, wherewith he could convert gold into ſilver; they would beg to be excuſed believing ſo ſtrange a thing: and why? but becauſe they never ſaw the like perform'd; and had tied themſelves down to a narrow ſtrait-lac'd philoſophy, that would not ſuffer them to look abroad, into what nature and art can produce. But if Mr.* Boyle *has actually done the thing; and others, men of veracity, have aſſured him they had done it too; is he credulous for believing it? Thoſe rather were ſo, who, without ſufficient evidence, raſhly concluded the thing impracticable.*

Since Mr. Boyle *aſſures us, and gives us ſufficient grounds to believe, that he has rendered ſilver, gold, fixed alkalies, &c. volatile; converted acids into alkalies; produced light from a de-*

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deſpicable dark ſubſtance; immediately reſtored fetid, and corrupted water, by precipitating from it a ſubſtance not fetid; diſſolved the hardeſt bodies by innocent and potable liquors, without heat; produced cold by a mixture of warm bodies; heat by a mixture of cold ones; warm'd cold liquors by ice; inſtantly froze ſpirit of wine; converted that ſpirit into water; water and fixed alkalies into earth; and performed numberleſs other ſurprizing things, that appear as ſo many contradictions among the unſkilful; may he not, with good reaſon, ſpeak of them as feaſible, and proper to be tried by others? or may he not, upon the ſtrength of human teſtimony; upon the relation of his friends and acquaintance, believe that other men have done the ſame, or even greater things than theſe; tho' himſelf was not an eye-witneſs of them? If, after having made his liquid phoſphorus in England, *he ſhould be aſſured that another chymiſt had made a ſolid one in* Germany; *if, after having invented his air-pump, he ſhould have heard, that many unſuſpected diſcoveries were made by means of it; if having converted gold into ſilver, eye-witneſſes ſhould inform him, that ſilver has been converted into gold; or if having himſelf prepared a menſtruum, almoſt as ſtrange as the alkaheſt; could he be reproached with credulity, for believing, that* Paracelſus *or* Helmont, *might poſſibly poſſeſs it in greater perfection; or that the other things were done by others? This, ſurely, is not unphiloſophical, or irrational. Mr.* Boyle *was too wiſe to ſet any bounds to nature; he was not forward to ſay, that every ſtrange thing muſt needs be impoſſible, becauſe he ſaw ſtrange things every day; tho' he always acknowledges, and it was a common ſaying with him, that "thoſe who had ſeen them, "might better believe them, than thoſe who had not." He modeſtly thought, that all we have to do is, to keep our eyes open, and expect what nature and art will, upon due application, perform. He was well aware, that there are powerful agents in the world, whoſe laws, and manner of acting, we want to be acquainted with. A man of a different caſt, or an ignorant* Indian, *who had never look'd abroad, and ſeen the common phenomena, would ſcarce credit the moſt faithful and exact relation that could poſſibly be made him, of the properties*

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and effects of the load-ſtone, or of gun-powder, by perſons of the greateſt veracity. But his ignorance alone is the cauſe of this incredulity. Propoſe the ſame things to a man who never heard of gun-powder, or the load-ſtone, but is otherwiſe a general philoſopher; and he will readily and thankfully yield his aſſent, and ſollicit you to ſhew him the experiments. This we may certainly depend upon, what Mr. Boyle *delivers as an experiment or obſervation of his own, is related in the preciſe manner wherein it appeared to him: no one ever yet deny'd, that he was a man of punctual veracity. And what he delivers as received from other hands, if it be any thing extraordinary, the reader will find that he does it with a manifeſt diffidence, and in a quite different manner from that wherein he gives us facts upon his own knowledge; and never entertains it for truth, without producing ſomething analogous or parallel, to countenance it, from his own obſervations or experience; always reſerving to himſelf the full liberty of believing no more than he ſees reaſon for. And what can a man do more than this, to avoid the imputation of credulity? On the contrary, do not thoſe who, without evidence, and merely from common report, believe Mr.* Boyle *to have been credulous, give us a remarkable inſtance of their own credulity? Wherever our author believes more than other men, it is becauſe he had more reaſon for it than they. 'Tis the general way, indeed, when a ſtrange thing is related, either poſitively to deny it as impoſſible, or directly to entertain it as a truth. This is making ſhort work of it. But Mr.* Boyle *poſſeſſed, in a great degree, that noble faculty of ſuſpending his judgment; till, by all the inquiries he could any way make, he received fuller information; and then the thing be found would determine it ſelf.*

Thus much, I hope, may juſtify my ſaying, 'tis with exquiſite judgment that Mr. Boyle *conducts his reader thro' all the regions of nature. I preſume, it will appear too, that beginning at the fundamental principles of things, he at length leaves him qualified to purſue any enquiry he ſhall think fit to go upon.*

'Tis impoſſible in a ſmall compaſs, to particularize all the diſcoveries which Mr. Boyle *has made in the ſeveral branches of natural knowledge; nothing leſs than the abridgment it ſelf can*

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can ſuffice for this purpoſe: and there the reader will find himſelf enrich'd with new notions, new ſenſations, new reflections; not a product of nature, not a ſingle plant, animal or mineral, no not a part of them, but may contribute to our delight, inſtruction, and advantage.

Mr. Boyle *is altogether taken up with the objects around us, and of which we are, or may be put in poſſeſſion; tho' we remain ignorant of their properties, virtues, and uſes, till he calls them out, ſets them before us, and ſurprizes with a ſight of our own ignorance of things ſo near us, ſo momentous in themſelves, and ſo neceſſary to our well-being, and the true enjoyment of life. There is no profeſſion or condition of men, but may be benefited by the diſcoveries of our author. As he had a wonderful comprehenſive genius himſelf, he has improved every part of natural knowledge; and the world is more obliged to this ſingle man, than to a thouſand vulgar philoſophers taken together. 'Tis certain, that he laid the foundations of almoſt all the improvements which have been made ſince his time, in natural philoſophy; and actually himſelf performed abundance of thoſe very things, and, perhaps, in a much better manner too, whereby ſeveral famous men have gained a reputation, in putting them off for their own diſcoveries. A very fine collection of uſeful knowledge, publiſhed as the works of a foreign ſociety, bears a remarkable teſtimony to this truth. The mechanic, the merchant, the ſcholar, the gentleman, all are benefited by* Mr. Boyle. *He ſhews us trades in a new light, and makes them, what they really are, a part of natural philoſophy; and, conſidering them accordingly, reveals ſome of their myſteries; all along advancing proper means to encourage, promote, and multiply the arts themſelves. The goldſmith, the lapidary, the jeweller, the refiner, the ſtone-cutter, the dyer, the glaſs-maker, artizans of all kinds, will from him receive the beſt informations, as to the working, managing, and employing to advantage their various commodities, materials, engines, and inſtruments. The huſbandman and the diver are here inſtructed in their arts; and the mineraliſt, the miner, and aſſayer, to find and ſeparate their ore to the greateſt profit; to encreaſe the quantity, to meliorate, improve, and enrich their metals; to purify and fine*

fine them, and accurately to distinguish the genuine and pure, from the adulterate, base, or counterfeit. The architect and builder are shewn how to chuse the best materials for their several purposes; the painter to make, to mix and improve his colours, and no part of mankind is neglected by Mr. Boyle. *But he shews a more particular regard to those professions, wherein the health of the species is nearly concern'd. The physician, the anatomist, the apothecary, and the chymist, are most highly indebted to Mr.* Boyle. *He has considered and improved the art of medicine in all its branches. We owe to him the best ways we have of distinguishing genuine drugs from adulterate; the discovery and preparation of several valuable medicines; with the manner of applying abundance to good advantage. He has shewed us the way wherein specifics may act; how to judge of the wholesomeness and unwholsomness of the air, of water, and of places; and how to examine, and make choice of mineral springs. In a word, there is scarce an art, or natural production known, but he makes some useful discovery or improvement in it.*

Then for his temper, it was most open, candid, generous, and communicative. He endeavours to make all the things he treats of, plain, easy, and familiar. There is no deep knowledge in mathematics, or algebra, previously requisite to understand him fully: no tedious systems need be read, to prepare us for reaping all the advantages of our author's philosophy. He brings us at an easy rate acquainted with the most useful things in nature; and this all the world agrees to be the highest excellence in a philosophical writer. The Memory of Mr. Boyle *will be dear to posterity, whilst that of mystical and enigmatical writers, such as study to make things difficult, and envy mankind their knowledge, shall meet with the disregard and contempt they deserve. What principally recommends our author, and distinguishes him from the vulgar herds of chymists, naturalists, and philosophers, is this humane temper, this open, candid, generous, and beneficent disposition. He was at immense pains and charge, in making his enquiries; he spared no time, no money, no diligence, in pursuing discoveries for the public advantage; without any sordid view to encrease his own fortune, which he hap-*

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happily thought sufficient of itself. His beneficent and public spirit made the world a generous present of all the fruits of his labours, without the least expectation of reward from them. His soul was as great and noble, as his genius was comprehensive, or his invention fruitful. And what shews him in the most amiable point of light, he was far above the selfish pleasure, of being admired for a genius, or raising a reputation by his discoveries. Tho' he wanted no capacity, or abilities, to have work'd up a glorious system, and erected a more pompous, ostentatious, and, perhaps, a more durable structure of natural or chymical philosophy, than had ever appeared in the world before; he nobly despised this poor satisfaction, and mean gratification; telling us plainly and expressly, that, notwithstanding all he had done, all the labour, pains, and expence, bestowed in a life of natural enquiries; notwithstanding the vastly numerous and important observations and discoveries he made, he frankly and ingenuously owns, that he saw nothing but the first dawnings of science; has drawn only the rudiments of natural knowledge; and leaves it in charge to posterity, for their own sakes, to consider him but as a beginner; and to pursue philosophical inquiries in general, without stopping to raise petty systems by the way. Here was a noble soul! This the desirable character! A true philosophical mind, well seasoned with humanity, beneficence, goodness! After he had led us thro' all the regions of nature; considered her various productions; shewed us their uses, and the manner of converting them to our several purposes; convinced us, that we live in a world most wisely contrived, wherein numberless grand designs are at once carried on with unceasing variety; and manifested that all the beings, and all the bodies we know, jointly conspire, as one whole, in bringing about the great ends of nature; he bids us not stop here, but leaves us full of assurance, that the farther we enquire into the works of the universal architect, the more beauty and harmony, the greater use and satisfaction we shall find among them; and this as long as the frame of the world endures. These noble, manly, and generous notions, are what the reader will find inculcated thro' the phi-

philoſophical writings of Mr. Boyle ; *whoſe principal aim, and great delight it was, to benefit mankind by them : and this valuable end I ſhall count it happy, in any degree to promote, by having fitted and prepared them for the ready and commodious peruſal of every reader.*

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A Preliminary

DISCOURSE,

Extracted from

Particular Pieces of Mr. *BOYLE*;

And Serving as a GENERAL PREFACE to his PHILOSOPHICAL WRITINGS.

THIS, in my opinion, one of the principal impediments to the advancement of natural philoſophy, that men have been ſo forward to write ſyſtems of it. When an author, after having *cultivated* only a particular branch of phyſics, ſets himſelf down to give a complete body of them, he finds himſelf, by the nature of his undertaking, and the laws of method, engaged to write of many things wherewith he is unacquainted; whence he is reduced, either idly to repeat what, perhaps, has already been impertinently deliver'd on the ſubject; or to ſay any thing of it, to avoid ſaying nothing. But the ſpecious and promiſing titles of theſe ſyſtem-writers are apt to perſuade the unwary, that all the parts of natural philoſophy have already been ſufficiently explain'd; and, conſequently, that it were needleſs for them to be at any farther expence and trouble in making enquiries into nature; the buſineſs being done to their hands.

And no leſs prejudicial is the way of writing to the reputation of the author himſelf. For it frequently happens, that when a writer, to vent a few particular notions, or diſcoveries of his own, preſumes to give a body of philoſophy, that part which is truly his, tho' excellent in its kind, ſeems either loſt in the crowd of things he has borrowed from others, and ſo comes to be overlook'd by the reader; or elſe the tedious and ungrateful repetitions of things, ſeveral times read in other authors, occaſions the whole book to be thrown aſide, as a rhapſody of trite and vulgar notions, unworthy the peruſal: whence, what wou'd

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have made an excellent and ſubſtantial eſſay, paſſes but for a dull and empty book.

The worſt inconvenience is ſtill behind; for whilſt this vanity of writing, either ſyſtems, or nothing, is indulged, many uſeful notions or experiments, are by ſober and modeſt men ſuppreſs'd; becauſe their judgment and integrity forbid them to teach more than they underſtand, or to aſſert more than they can prove: whence, of conſequence, this pernicious cuſtom prevents them from publiſhing their thoughts and obſervations, till they are numerous enough to ſwell a ſyſtem. So that I am afraid the ſyſtem-writers have hinder'd the world from much more uſeful compoſures than their own. For there are very few men, if any, enrich'd with a ſufficient ſtock of experiments and obſervations to make out clearly and ſolidly, I will not ſay all the phenomena of nature, but of any ſubordinate branch of phyſics. And thoſe who are diligent and judicious enough, thoroughly to ſtudy any part of philoſophy, will, from the difficulties and uncertainties they find therein, be the moſt backward of all men to write ſyſtems.

And what we have thus ſaid of univerſal ſyſtem-writers, is proportionably applicable to thoſe who pretend to give us complete accounts of chymiſtry, or any other conſiderable and comprehenſive part of natural philoſophy. Tho' I muſt own, that from theſe attemps, which are much leſs difficult than the former, mankind has received conſiderable advantages; how ſhort ſoever the authors may have fallen of their pompous titles. Nor would I diſcourage the publication of a ſyſtem of philoſophy, or any part of it, from time to time, by ſome very intelligent writer, taken from the beſt authors and obſervations then extant; for ſuch a work may be ſerviceable in many reſpects, if it contain any conſiderable improvements in knowledge, more than the laſt work of the ſame nature. But, for my own part, I am very ſenſible of the want of a ſufficient ſtock of experiments and obſervations, to write ſyſtematically. And, indeed, I cannot but impute many of the deficiencies in the reaſonings of *Ariſtotle*, and other celebrated philoſophers to their having too haſtily, and without due obſervation, or a ſufficient number of experiments, preſum'd to deliver axioms, and eſtabliſh principles. For the theories that are built but upon a few obvious experiments, are very liable to be overthrown by a fuller enquiry into nature. And, truly, if men were willing to regard the advancement of philoſophy, more than their own reputations, it were eaſy to make them ſenſible, that one of the moſt conſiderable ſervices they could do the world is, to ſet themſelves diligently to make experiments, and collect obſervations, without attempting to eſtabliſh theories upon them, before they have taken notice of all the phenomena that are to be ſolved. I wou'd not, however, debar men from reaſoning upon experiments, and endeavouring to diſcern, as early as poſſible, the agreements, differences, and tendencies of things; ſuch an abſolute ſuſpenſion of the rational faculty is, perhaps, impoſſible; at leaſt, 'twould be

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be exceeding irkſome. It ſometimes conduces to the diſcovery of truth, to frame an hypotheſis to ſolve a difficulty; for the underſtanding may be inſtructed, even by its own errors. What I wiſh for, with regard to ſyſtems, is, that men would always procure a number of experiments proportionable to the extenſiveneſs of the theory to be built upon them*: and, in the next place, that ſuch kind of ſuperſtructures ſhou'd be look'd upon only as temporary, and preferable, indeed, to others, as being the leaſt imperfect; yet not entirely to be acquieſced in, as incapable of farther improvements and uſeful alterations.

Thus much for the inconveniencies of the ſyſtematical way of writing; whereto that which we, in imitation of the *French*, call eſſay, ſeems directly oppoſite.

'Tis, certainly, a great convenience to this latter manner of writing, that the reader need not be tired with tedious repetitions of what others have ſaid; and that the author, being at liberty to break off when he pleaſes, is not obliged to endeavour to teach what he does not underſtand; or to write of any ſubject, unleſs he can do it well. And if ſuch eſſays be, as they ought, but competently ſtock'd with experiments, 'tis the reader's own fault if he does not improve by them†. When an author acquaints me only with his own thoughts or conjectures, if he miſtakes in his reaſoning, I am in ſome danger of erring with him; at leaſt, I may loſe all the time and pains I beſtow upon him: but if a writer endeavours, by enriching his diſcourſe with new and real obſervations or experiments, to credit his doctrine; let his private opinion be ever ſo erroneous, yet his experiments being true, I may make my own uſe of them; and even plead them againſt his opinion: ſo that ſuch a writer will certainly teach me uſeful truths, and cannot eaſily lead me into error.

From hence, then, appears the great uſefulneſs of experimental eſſays in general.

As for the manner wherein my own are written, I have, thro' the whole, aimed at a plain philoſophical ſtyle, and clear ſignificant expreſſions, rather than ſuch as are ornamental. And, certainly, where our deſign is to inform, not to delight, or perſuade, perſpicuity is one of the beſt qualifications in ſtyle; and to affect rhetorical flouriſhes in

* No philoſopher appears to have obſerved this rule more exactly than the incomparable Sir *Iſaac Newton*: and, accordingly, as his theory is very extenſive, ſo are his experiments numerous; but being always wonderfully ſimple, and well choſen, a few of them compared together, ſoon lead to greater diſcoveries, than many times their numbers wou'd, when contrived by vulgar heads, and executed by vulgar hands. Such a ſagacity in finding out the leading experiments of an enquiry, and executing of them in the ſhorteſt ways, is the higheſt qualification in an experimental philoſopher. Mr. *Boyle* had a great talent in thus contriving experiments, and bringing things to the trial; eſpecially when he could be accommodated with proper engines and inſtruments.

† All Mr. *Boyle*'s philoſophical pieces, are properly eſſays, well ſtock'd with experiments and obſervations.

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ſetting down an experiment, or in explaining ſome abſtruſe phenomenon, were as improper as to paint the eye-glaſs of a teleſcope, where clearneſs alone is the thing requir'd. 'Tis not an unpoliſh'd philoſopher, but the prince of orators, *Cicero* himſelf, who ſaid, "whatſoever is "clearly expreſs'd upon a good ſubject, appears to me to be excellently "ſpoken; to affect elegance in ſuch a caſe were childiſh; to ſpeak "plainly and intelligibly here, is what a wiſe and a learned man wou'd "chooſe."

I expect it will be obſerved to my diſadvantage, that I ſpeak doubtfully upon moſt occaſions; which ſeems to argue a diffidence of the opinions I incline to: but having met with many things, for which I cou'd aſſign no probable cauſe, and with ſome, for which many very different ones might be alledg'd; I dare ſpeak poſitively and confidently of very few things, except of matters of fact. 'Tis not that I condemn the practice of bolder men, who attempt to ſolve the moſt abſtruſe phenomena of nature; I admire them, where their endeavours ſucceed; and tho' they fail, applaud them: but a man ſhould know his own abilities, and not imitate all he thinks fit to praiſe. 'Tis, I am ſenſible, the ready road to fame, to ſolve phenomena, and propagate opinions; but by the way of writing to which I have condemned my ſelf, I can hope for little better than to paſs for a drudge, of greater induſtry than reaſon; and fit only to collect experiments, for more philoſophical heads to make uſe of and explain. And I am content, provided experimental knowledge be really promoted, to contribute to the meaneſt way to advance it; and had rather be an under-builder, and even dig in the quarry for materials towards ſo uſeful a ſtructure, than not aſſiſt in erecting it. But, to ſay the truth, I have not been wholly wanting in framing notions, and deviſing hypotheſes, free from the deficiencies and errors I obſerv'd in thoſe of other men; tho' with this ſucceſs, that I have hitherto commonly found what pleaſed me for a while, as ſquaring with the obſervations on which my notions were grounded, was ſoon after contradicted, or diſgraced by ſome new experiment or obſervation, either before unknown, or unthought of. And thus it has fared with many eminent writers, who have taken upon them to deliver the cauſes of things, and explain the myſteries of nature, and their doctrines, after having, for a ſhort time, been applauded and admired, have been afterwards confuted by the diſcovery of new phenomena.

Notwithſtanding all this, I have on ſome occaſions, ventured to deliver my opinion; becauſe I rather chooſe to run the hazard of being ſometimes miſtaken, than not afford my reader the beſt aſſiſtance I could towards the diſcovery of truth. And becauſe in my ſolutions, and explanations of natural effects, I have not always an immediate recourſe to the magnitude, figure, and motion of atoms, or the component particles of bodies, 'tis proper I ſhould give my reaſon for this procedure. For many men of learning, and eſpecially phyſicians, are

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in danger of being deſpiſed, on account of an opinion taken up from the miſapplied doctrine of ſome eminent *Atomiſts*, as if no theory in natural philoſophy cou'd be rational, where any other cauſes of things are aſſign'd, than atoms and their properties. But, in general, to aſſign a reaſon of an effect, is to deduce it from ſome other thing in nature, more known than it ſelf; and, conſequently, there may be ſeveral degrees of explaining the ſame thing. For tho' ſuch ſolutions are the moſt ſatisfactory to the underſtanding, which ſhew how the effect is produced by the more primitive and general properties of matter; yet thoſe accounts are not to be deſpiſed, that are taken from the obvious and familiar properties or ſtates of bodies; tho' theſe themſelves, probably depend on the more univerſal. In the ſearch after natural cauſes, every new meaſure of diſcovery both inſtructs and gratifies the mind; tho' the nearer the diſcovered cauſes approach to the higheſt in the ſcale of ſeries, the more is the underſtanding gratified and inſtructed *. 'Twou'd, therefore, be highly uſeful, if ſome mathematical genius were imploy'd, in deducing the principal modes or qualities of matter, ſuch as heat, cold, *&c.* with the ſtates and conditions of it, as fluidity, firmneſs, *&c.* from the primitive and ſimple properties thereof, as figure, motion, *&c.* In the mean time, we ſhou'd not reject all thoſe accounts of particular effects, which are not immediately deduced from the primary properties, but from the leſs univerſal qualities of things, as cold, heat, weight, *&c.* And this too wou'd much ſhorten the explanation of particular phenomena, which, otherwiſe, muſt be exceſſively tedious. Thus, he eaſily aſſigns a tolerable reaſon why all metals, except gold, ſwim upon quick-ſilver, who teaches, that thoſe metals are lighter than quick-ſilver, but gold heavier; tho' he does not deduce the phenomena from atoms, nor ſay why gold is heavier, or aſſign the general cauſe of gravity. Thus a phyſician will tell you, that rhubarb cures a looſeneſs, by a laxative virtue, whereby it carries off the cauſe, and an aſtringent property, whereby it afterwards ſtops the flux: but, if you aſk him, why rhubarb purges, he will hardly give you a ſatisfactory anſwer. Yet a ſkilful phyſician would think himſelf injured, if the reaſons he renders of things in his own profeſſion, were denied to be reaſons, becauſe not built upon atomical principles. And, indeed, there are often ſo many ſubordinate cauſes of

* 'Tis unphiloſophical to reſolve effects into the original cauſe of all things, the ſupreme Being, without an abſolute neceſſity. Indeed, by diſcovering more intermediate cauſes, we only lengthen the chain, and muſt end in the author of nature at laſt; but it is the buſineſs of philoſophy, to diſcover all theſe links, and to *ſhew*, if poſſible, how the laſt is connected with the reſt. Many philoſophers tell us, that gravity is, doubtleſs, immechanical, and muſt be immediately reſolved into the will of God; yet Sir *Iſaac Newton*, with great ſagacity, has nobly attempted to give a mechanical account of it. The practice, therefore, of this illuſtrious author, as well as of Mr. *Boyle*, ſhews, that philoſophers ſhou'd not be too haſty, in ſolving phenomena from the will of the Creator; becauſe it tends to ſtop the progreſs and advancement of natural knowledge.

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of things, that a large field is left therein to exerciſe human induſtry, in ſolidly deducing the properties of bodies, from more general and familiar qualities; and, alſo, intermediate cauſes from one another. And we ſhould the more readily allow of ſuch cauſes as theſe, becauſe there are ſome things, for which no phyſical cauſes are at all aſſignable; as of the origin of local motion, for inſtance.

There are two very different ends in ſtudying natural philoſophy; to pleaſe a man's ſelf in the cauſes of the diſcovery of known phenomena, and to be able to produce new ones. Now, as the atomical principles are likely to give moſt ſatisfaction in the knowledge of cauſes; ſo philoſophy may be purſued with great pleaſure and delight, by collecting and making a variety of experiments, and obſervations. When an engineer employs gun-powder, 'tis not neceſſary he ſhould know the ingredients whereof it conſiſts, or the proportions wherein they are mixed; the common notion of this powder, will enable him to perform ſurprizing things with it. And a phyſician, who has obſerv'd the medicinal virtues of *Venice*-treacle, may, tho' he know not the names or nature of the numerous drugs whereof 'tis compoſed, cure ſeveral diſeaſes with it. 'Tis, indeed, an advantage, as well as a ſatisfaction, to know, in general, how the qualities of things are deducible from the primitive properties of the ſmalleſt parts of matter; yet if we are only acquainted with the qualities of the bodies they compoſe, and how theſe are diſpoſed to operate upon other bodies, and to be wrought upon by them, we may, without aſcending to the top of the ſeries of cauſes, perform things of great moment. Artificers, who never dream'd of the *Epicurean* philoſophy, have accommodated mankind with a multitude of uſeful inventions. But to return.

I have purpoſely refrain'd from ſwelling my diſcourſe with ſolemn and elaborate confutations of other men's opinions, except in ſome few particular caſes, where I thought they might prove greater impediments to the advancement of experimental knowledge: and even ſuch opinions I have been cautious in oppoſing, unleſs with experimental objections. For I deſign not to engage with any ſect of philoſophers. I wou'd endeavour to deſtroy the groundleſs ſtructure of opinions, as fancaſtical objects are aboliſh'd by letting in more light upon them. And experience ſhews, that many plauſible and radicated opinions, have been thus demoliſhed. Indeed, ſuch opinions will vaniſh of themſelves, tho' no body ſhould expreſly write againſt them.

'Tis, alſo, contrary to my inclination, to tranſcribe paſſages out of authors, which commonly add much more of bulk, than of worth, to a book. But where particulars are of that nature, or moment, as to require proof or illuſtration, I have ſometimes been obliged to comply with this cuſtom; tho' I always apeal to other writers, not as judges, but as witneſſes.

I muſt here apologize for one thing that is very contrary to my nature, the concealing ſome particulars in my writings. But theſe are ſuch

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ſuch as I either had upon condition of ſecrecy; ſuch as are made a pecuniary advantage of by ſome particular perſons; ſuch as I purpoſely keep by me to exchange for the ſecrets of others; or, laſtly, ſuch as are eaſily capable of being converted to ill uſes. The reader, therefore, muſt not think himſelf unkindly dealt with, if, upon theſe conſiderations, ſome proceſſes and receipts are kept from him. The number of theſe, however, is but ſmall; and he has ample amends made him by a large collection of others freely preſented him.

To excuſe the prolixity uſed in ſetting down many of my experiments, I might repreſent that moſt of them being wholly new, required to be circumſtantially deliver'd, to gain them a thorough aſſent; but the principal reaſon of this was, my deſigning them to ſerve as full and faithful records of the things themſelves; whereby they might ſave others the trouble or expence of repeating them.

If any one ſhall think, that in my diſcourſes I reveal too much of the ſecrets and myſteries of trades, I would have them conſider, that my deſign being to inſtruct, and ſometimes to convince my reader, I was frequently driven to make uſe of ſuch ſenſible and obvious experiments, as eaſily gain credit, or may be ſeen with little trouble: and becauſe I write for philoſophers, not to inſtruct men how to raiſe eſtates, I ſeldom divulge more than an experiment or two in any particular trade, which is far from enabling a perſon to practiſe the whole of that trade. But ſuch benefits may accrue to trades from a philoſophical conſideration of them, that the artiſt might well excuſe the being made free with upon ſuch an occaſion. The inventions of philoſophical heads, ſet great numbers of mechanical hands to work; and furniſh them with means of procuring not only a ſubſiſtence, but eſtates too. The truth is, I have been the more particular upon this ſubject, in hopes of removing philoſophy from the ſhops into the ſchools; which might prove as ſerviceable to trades themſelves, as to the hiſtory of arts and nature. And I ſhall not think my labour loſt in recording what may to ſome appear trifling experiments, if by ſtriking in with the humour or genius of my reader, any one of them ſhall give him a reliſh for experimental knowledge: for the pleaſure, variety, uſefulneſs, and other endearing qualities of that purſuit, muſt ſurely invite him to a farther progreſs, whereby many great advantages may be derived to the world. Natural philoſophy is not that barren thing it has been long accounted: I only wiſh that I could rouze up the generality of inquiſitive perſons, and excite the curioſity of mankind to the making of experiments; from which alone the greateſt advancement of uſeful knowledge is to be expected. To encourage and facilitate this practice, give me leave here to propoſe a general method of drawing up the proper heads of enquiry for philoſophical ſubjects; according to the model whereinto my own ſearches into nature were generally directed.

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In the firſt place, I propoſe to my ſelf three ſorts of heads, whereto all the particulars which occur, belonging to the hiſtory of a ſubject, whether it be a body, a quality, an operation, or a proceſs, may conveniently be referr'd. Theſe diſtinct ſets or topics of enquiry, I call orders, ranks, or claſſes. And finding that things of different natures were referable to each ſet, for inſtance, queries, propoſitions, *&c.* I choſe to take in all theſe kinds of topics, or articles of enquiry, under the general and comprehenſive name of titles. The firſt order of theſe titles I made to conſiſt of ſuch as readily occurr'd, upon the primary deliberate view, or general ſurvey of the ſubject. For a man can hardly be ſo clear-ſighted, or ſo happy, as at a firſt attempt to light upon ſuch ſhort, direct, and advantageous methods of digeſting, and delivering his diſcoveries, as might afterwards be afforded him by a thorough enquiry, and farther informations. It may, therefore, ſuffice for the firſt, that the mind takes a general ſurvey of the ſubject, views it on every ſide, and obſerves the different proſpects it affords. There is no need of being very ſcrupulous in enumerating and ranging the particulars referable to this claſs; but only to order it ſo, that the titles may be ſufficiently various and comprehenſive, rather than exactly methodical, or accommodated to any particular hypotheſis. And becauſe, even at the firſt deliberate view, ſome of theſe titles may appear ſo conſiderable and fruitful, as to deſerve that ſeveral ſubordinate and more particular topics be referr'd to them; I call the capital titles, or thoſe of this firſt claſs, primary, and the ſubordinate ſecondary titles.

Now, when by reading, conference, meditation, and the experiments ſuggeſted by the heads of the firſt claſs, we have receiv'd the fulleſt information we can procure, of every thing that relates to the ſubject; we may then proceed to form another ſet of titles, to be call'd the ſecond, or, if no other interpoſe, the laſt claſs; which, if we have been diligent and ſucceſsful, will be more copious, and better ranged than the firſt. For, many things will now, probably, appear to belong to the ſubject, which before were thought remote from it; or, perhaps, not thought of at all: and farther diſcoveries will enable us to correct the order of the former titles. Moſt of the particular heads too will, probably, appear more comprehenſive, and of larger extent, than was before imagin'd; ſo that a particular title may hence be properly branch'd out into ſeveral ſubordinate articles, or ſecondary titles; one whereof alone will, perhaps, comprize as many experiments, or obſervations, as at firſt ſeem'd to belong to the primary, or more general title it ſelf. And from the materials thus orderly drawn together, under this laſt claſs, with the requiſite changes in point of method, connection, tranſitions, and additions, may be form'd the beginning of a natural hiſtory of the ſubject whereto they bear relation. For, even after all this is done, the hiſtory will, in all probability, be only begun, not compleated; the nature of things, and the induſtry of ſkilful men being ſo fertile, that the hiſtory will, doubtleſs, be encreaſed, cor-

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corrected, and improved from time to time; but never, I fear, in many ages, arrive at abſolute perfection.

When the ſubject to be treated, is either very comprehenſive, or very difficult; as thoſe of animal generation, magnetiſm, fermentation, gravity, *&c.* it will be uſeful, if not neceſſary, to interpoſe between the titles of the laſt, and of the firſt claſs, a ſet that may be called of the middle order; for the framing whereof the nature of the ſubject muſt be narrowly ſcann'd, ſurvey'd afreſh, and carefully compared with the ſeveral particulars, obtain'd and diſpoſed under the titles of the firſt claſs. Hence many new hints, and heads of enquiry will, in all likelihood be ſuggeſted; which, added to the former, may deſerve to have a new claſs fram'd for them, conſiſting of articles more copious and various than the firſt; and fit to be ranged in a different order. Theſe ſeveral titles are to be touch'd and fill'd up, after the ſame manner that the *Iſraelites* gradually acquired a knowledge of the fruitful land of *Canaan*, before they poſſeſs'd it: at their firſt entrance, the ſpies took a tranſient view of the country, and brought back but an inaccurate account thereof, with a little of the more remarkable fruit it afforded; but upon a ſecond expedition, taking pains to gain fuller inſtructions, they return'd able to anſwer many particular articles of inquiry: and this latter induſtry wou'd enable them to give a far more diſtinct and ſatisfactory chorography, or ſurvey of the country, than they cou'd have furniſh'd out before their ſecond expedition.

Laſtly, as 'tis not to be expected, that the titles, whether primary or ſecondary, of a natural hiſtory, ſhou'd need no enlargement, or reformation from ſecond thoughts, and a more comprehenſive practical knowledge of the ſubject; I always thought it neceſſary to annex to the firſt edition, if I may ſo call it, of my titles, an appendix, conſiſting of things omitted and things to be added; the former whereof are properly referable to ſome of the titles already enumerated, and only thro' haſte, or overſight, had not their places aſſigned them; but the latter, were to receive ſuch new particulars, as ſhould be ſuggeſted by farther advancements, after the hiſtory was written; whether they directly belong'd to any of the preceding titles, or might, only in a general way, contribute to the knowledge or illuſtration of the ſubject.

To proceed, I muſt obſerve, with regard to the mechanical contrivances employ'd in the execution of my experiments; that tho', in general, they anſwer'd my purpoſe, yet much more artificial inſtruments may be invented. But being frequently obliged to make my experiments at a diſtance from *London*, I was glad to put in practice the beſt methods I could any way deviſe, where all deſirable conveniencies were not to be had. Indeed it has been no ſmall hindrance to the advancement of natural philoſophy, that ſome nice critics are ſo rigid in exacting the very beſt contrivances, in thoſe who publiſh their experiments; for every philoſopher has not a mechanical head. And he

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may well be eſteem'd a benefactor to natural philoſophy, who barely contrives experiments in theory, or propoſes practicable ways of bringing things to a trial: for the increaſe of knowledge is the product of the things themſelves that are diſcover'd; whatever means or inſtruments are uſed in the diſcovery of them. 'Tis true, in curious and extraordinary caſes, perfection in the contrivance may be deſirable, uſeful, or even neceſſary; yet in many others, where only the production of a new phenomenon is the thing intended, he contributes to the hiſtory of nature, who really performs the ſubſtantial part of a diſcovery, tho' it be not in the moſt eaſy, moſt perfect, and moſt compendious method imaginable. *Archimedes* himſelf, if hiſtory ſays true of him, went a much more laborious and inaccurate way to aſſign the proportions of gold and ſilver, in a mixture of thoſe two metals, than is taught us by the modern hydroſtatics; tho' this, perhaps, wou'd have remain'd undiſcover'd. but for the hint afforded by his method of procedure.

To prevent, as much as poſſible, the neceſſity of cuts, or the figures of the inſtruments which I employ'd in my experiments, I have made the relations and deſcriptions of them full and plain; yet, leſt my own habit of deviſing various trials, and the frequency of ſeeing them put in practice, might have led me to imagine things more intelligible than the generality of readers would find them, I adviſed with ſome proper perſons, as to the experiments neceſſary to be illuſtrated with ſchemes or figures: which are ſo contrived, as generally, by inſpection, to expreſs and clearly repreſent the things they were deſign'd to ſhow; without referring, by letters, to the particular parts whereof they conſiſt.

There is another particular, which muſt not be paſſed over in ſilence, the frequent repetitions to be met with in my writings. Having often been obliged to write at a great diſtance, as well of place, as of time, from the books that I had formerly publiſh'd; and ſo wanting the opportunity of conſulting them; the mention of things already there deliver'd, was render'd ſometimes unavoidable: tho' I hope theſe generally appear on ſuch different occaſions, ſerve ſuch different purpoſes, and are attended with ſuch additional circumſtances, that the reader will not be diſguſted to meet with the ſame thought in different parts of my works.

Give me leave in the laſt place, to explain my ſelf, as to the opinion which I may ſeem to have entertain'd of chymiſtry; and as to the uſe I have made of it in my philoſophical inquiries.

After having gone thro' the common operations of that art, and coming ſeriouſly to reflect upon them, I thought it pity that inſtruments, which might prove ſo ſerviceable to natural philoſophy, ſhou'd be ſo little employ'd to advance it. I ſaw that ſeveral chymiſts had, by a laudable diligence, obtain'd various productions, and hit upon

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upon many more phenomena, conſiderable in their kind, than could well be expected from their narrow principles; but finding the generality of thoſe addicted to chymiſty, to have had ſcarce any view, but to the preparation of medicines, or the improving of metals, I was tempted to conſider the art, not as a phyſician, or an alchymiſt, but a philoſopher. And, with this view, I once drew up a ſcheme for a chymical philoſophy *, which I ſhou'd be glad that any experiments or obſervations of mine might any way contribute to complete.

There are many men, who, having no knowledge of chymiſtry but by report, entertain a very diſadvantageous opinion, both of the art, and thoſe who profeſs it, and becauſe it has been too often practiſed by illiterate arrogant impoſtors, they will ſcarce allow a philoſopher to underſtand or ſtudy it. But, ſurely, without ſeeking after the grand elixir, this art may greatly promote our knowledge of the works of nature. 'Tis certain, that by means of it, ſome meliorations of metalline and mineral bodies may be made, uſeful medicines prepared, and various productions ſerviceable in particular trades, and ſeveral occurrences of human life, obtain'd. And tho' this alone ſuffices to ſhew, that a man might ſtudy chymiſtry to advantage; yet, as I before intimated, I had a larger view in cultivating it; and have attempted no leſs than the advancement of natural philoſophy, by means thereof. And, I hope, I ſhall have done no unacceptable ſervice to the common-wealth of learning, if, by my acquaintance with this art, I beget a good underſtanding betwixt the chymiſts, and the mechanical philoſophers, who certainly have hitherto been too great ſtrangers to each other's diſcoveries.

I cou'd, indeed, have ordinarily employ'd more conſiderable chymical experiments in my eſſays, but thought fit to give the preference to ſuch as were ſimple, ſhort, and eaſy, and ſuch as might be made at a ſmall expence; becauſe theſe I judged the fitteſt foundations for a philoſophical theory. And the gratification of the chymiſt was not here ſo much my deſign as to oblige the philoſopher.

* A large part of that collection of experiments, which were made with a view to the chymical philoſophy here mention'd, Mr. *Boyle* afterwards thought fit to employ in giving the mechanical origin of qualities in bodies, and clearing up other philoſophical difficulties; whence tho' the major part of his eſſays have not the form of chymical ones, they are no other at the bottom. Nor does there ſeem to be any better method in nature, for improving natural Philoſophy, than that which builds upon genuine chymiſtry. A rational, and experimental eſſay of chymical philoſophy, which might be drawn from Mr. *Boyle*'s diſcoveries, and ſome others that have been made ſince his time, would open a ſurprizing ſcene in the works of nature; and prove infinitely more entertaining to the mind, and advantageous to human life, than a ſtranger to the various operations, numerous productions, and aſtoniſhing effects of philoſophical chymiſtry, can poſſibly imagine.

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But, as I may myſelf ſeem an enemy to the chymiſts, by oppoſing ſome of their tenets, I deſire it ſhould be obſerv'd, that I have a very different eſteem for the notional and for the practical part of chymiſtry. For I have been obliged to call in queſtion many of their tenets, not only as a philoſopher, but alſo as a chymiſt; becauſe they appear'd diſagreeable to the very foundations of philoſophy, and genuine chymiſtry it ſelf. Such an one, for inſtance, is the hypotheſis of the three principles in natural bodies. But as for the chymical operations, and eſpecially thoſe highly valuable ones, digeſtion and cohobation, I take them to be excellent tools in the hands of a natural philoſopher, who may apply them to many different, and, perhaps, nobler uſes, than thoſe whereto they are generally confin'd in laboratories; and by their means diſcover, imitate, correct, and, in ſome caſes even excel nature. I, likewiſe, diſtinguiſh betwixt the vulgar chymiſt, and the chymical philoſopher. For, we are told, there is in the world a ſet of men of a much higher order than thoſe who give us courſes of chymiſtry, or other books of that nature, able to tranſmute baſer metals into perfect ones, and to do ſome other things, that the generality of chymiſts confeſs to be extremely difficult, and ſome of them think impoſſible. What I have received from credible eye-witneſſes, and, perhaps, ſome more immediate arguments, ſtrongly incline me to think there may have been, and yet are, ſome ſuch men. And, whatever be thought of the philoſopher's ſtone, I confeſs my ſelf convinced, by what I have ſeen, that there are in the world as difficult *Arcana*, as many of thoſe which have been derided for chymical non-entities. And if ſuch men there are, I cannot but fancy them poſſeſs'd of ſome exceeding powerful menſtrua, whereby they may produce ſuch alterations in bodies, as we have no examples of. Thus much will ſerve to ſhew the chymiſts, that I am no enemy to their art; and, indeed, I think it eminently conducive to extend the empire of mankind, by enlarging our views, and giving us the command of nature. For, as the *Bolonian* ſtone, unleſs it were chymically prepared, wou'd never become luminous; ſo there are many other natural bodies, which never afford light to philoſophy, till 'tis ſtruck out to them by chymical operations.

I have nothing more to add, than that I am ſenſible of the great plainneſs in my writings, thro' the want of ſuch philological ornaments as learned men beſtow upon their productions; but I am not ambitious to appear a man of letters: I cou'd be content the world ſhould think I had ſcarce looked upon any other book than that of nature*. And, for my own part, I always eſteem him the moſt pro-

* Mr. *Boyle* appears, by his numerous writings to have beſtow'd ſo much of his time in natural inquiries, and yet enjoy'd ſo ſmall a ſhare of health, that he

profitable author, who does not endeavour to ſhow his own learning, but to encreaſe the knowledge of his reader.

he might well have been excuſed the pains of converſing with authors; but, to our ſurprize, he was a critic in the learned languages, ready in the uſe of ſeveral modern ones, and very well verſed in all the polite and ſeverer literature, both of the ancients and moderns.

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N. B. *Several of the different and independent treatises are usually included in the books of this catalogue; whilst only the first, and distinguishing part of their titles is here mention'd. The rest of Mr.* BOYLE's *philosophical pieces, taken into our abridgment, which occur not in any volume of the catalogue, are to be found in the* PHILOSOPHICAL TRANSACTIONS *or* COLLECTIONS.

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THE PREFACE.

TO shew the usefulness of a philosophy, is to shew its excellence. That the experimental kind is most highly useful, the following pages, by a vast variety of particulars, abundantly manifest. Indeed, the modern philosophy, which builds upon experiments, is wholly applicable to the purposes of life and the phenomena of nature; and seems now to be entirely prosecuted in that view; whereby it is advanced far above all the systems that went before it.

Since the late happy conjunction of mathematics and philosophy, and the application of them both to matter and the bodies about us, many noble discoveries have been made, all tending to enlarge the understanding and to give us a command over nature. To this end, the industry of the moderns has made use not only of later inventions, but also of those of the ancients. Thus, for example, the old geometricians demonstrated abundance of fine properties in the ellipsis and the parabola; and of late the motions of the planets, comets and projectils are demonstrated to be performed in these lines: an use the ancients never dream'd of! By this means, at length, a just theory of the celestial bodies is established, and the whole astronomical world level'd to our capacities. Hence another new scene is also open'd; for mathematicians, thus becoming mechanics, have furnish'd us with numberless new instruments and engines for various uses. Microscopes and telescopes, unknown to the ancients, are now commonly applied to discover the wonders of nature, both in her smallest and largest productions; and serviceable machines are every where employ'd to save the expence of animal strength; models and imitations are made of nature's works, and the world with its various phenomena clearly represented in miniature. In short, philosophy is brought down and confin'd to material objects, and such things as we know

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to have a real exiſtence; which is now allow'd to be the proper and only way of applying and improving it. And in this ſenſe Mr. Boyle *underſtands experimental philoſophy, and treats it accordingly.*

If any thing ſhall ſeem liable to exception in the following piece, either as to the matter or the ſtyle, the reader is deſired to take notice, that Mr. Boyle *wrote a great part of it whilſt he was very young, and the whole in a familiar epiſtolary way.*

THE

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THE USEFULNESS OF *Experimental Philosophy*; By WAY of EXHORTATION TO The STUDY of it.

In THREE Parts.

PART I.

Shewing the advantages that accrue from natural philosophy to the mind of man.

SECT. I.

AS the natural philosophy I wou'd recommend is much more difficult, laborious and expensive than that of *Aristotle* or the schools, 'tis necessary, before we descend to particulars, to apprize the reader of its ability to recompence whatever time and pains can be thereon bestow'd.

Our inquiries into nature rewarded by an increase of understanding and a power to do good.

And, methinks, a due reflection upon that saying of *Pythagoras*, the author of the modest title philosopher, "to know the truth, and to do good are "the

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" the things that chiefly enoble man, and make him reſemble the Gods" might endear the ſtudy of philoſophy to us. For, as the ſoul is endow'd with two principal faculties, the underſtanding and the will, the former whereof is adorn'd and perfected by knowledge, and the latter, improv'd and render'd amiable by goodneſs; ſo nothing more gratifies and enriches the one, or more enables the other to do good, than natural philoſophy.

But to ſhew this more diſtinctly, I ſhall here conſider a few of thoſe numerous advantages which accrue to mankind from the ſtudy of nature: the chief whereof tend to inſtruct the underſtanding, to gratify our curioſity, and to raiſe and cheriſh our devotion.

And as not only *Ariſtotle*, but common experience ſhews, that all men are naturally deſirous of knowledge; this propenſity muſt ſtrongly attach us to thoſe works of nature which are ever preſent to our ſenſes, and continually ſollicit our inquiries. Even the ſchool philoſophy, though ſo litigious in its theory and barren of fruit, has had its zealous admirers; who cou'd ſurely be render'd ſuch by nothing but this in-bred fondneſs for its pretended end and object.

Again, the ſame author, taught by *Plato*, obſerves that admiration by raiſing our curioſity is the parent of philoſophy; as we live, therefore, among wonders, they muſt of neceſſity ſtrongly invite us to a contemplation of nature's works; ſome whereof, being obvious and legible, amaze an ordinary ſpectator; whilſt others are admirable and abſtruſe enough to aſtoniſh the moſt curious and inquiſitive.

The bare proſpect of this magnificent fabric, the univerſe, furniſh'd and adorn'd with ſuch a ſtrange variety of curious and uſeful objects, might tranſport us with joy and wonder, did not their commonneſs prevent ſuch an effect. That this would otherwiſe happen, appears probable from what Mr. *Stepkins* the oculiſt, and another illuſtrious eye-witneſs, lately told me of a maid, who, being born with cataracts, continued abſolutely blind till about the age of eighteen; but being then brought to the free enjoyment of ſight, ſhe was ſo raviſh'd upon beholding the many new preſented objects, ſo tranſported at moſt of them, and, in a word ſo far diſtracted as to explain that myſtical *Arabian* proverb, " Shut the windows " that the houſe may be light."

But if a ſlight view of this admirable ſtructure be capable of pleaſing ſo highly, what ſatisfaction muſt it afford a ſpectator able to comprehend and reliſh the curious workmanſhip and contrivance of it? For the book of nature, I conceive, appears as differently to an ordinary gazer, and to a naturaliſt, as an excellent book of hieroglyphics wou'd to a child and to a philoſopher; the child wou'd be pleaſed with the oddneſs and variety of the pictures alone; whilſt the philoſopher wou'd not only be delighted with the ſame, but receive a much higher ſatisfaction in contemplating and acquiring the veiled and abſtruſe truths that were dextrouſly couched therein.

For as the underſtanding is the higheſt faculty in man, ſo are its pleaſures the higheſt he can naturally receive. I am not, therefore, ſurprized that *Archimedes*, when happening, in a bath, upon a way to ſolve a perplexing difficulty, ſhou'd inſtantly leap out, and run naked about the ſtreets, crying aloud, " I have found it. I have found it;" nor that the elder *Pliny* cou'd not be deter'd by the diſſuaſion

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diſſuaſion of friends, the flames and hideous eruptions of *Veſuvius*, from ſearching into the nature of ſuch *Vulcanos*, and, as it happen'd, from loſing his life by too near an approach. For, in like manner, we daily ſee chymiſts hazard their lives among their furnaces, whence the fumes that iſſue prove ſometimes fatal.

To converſe with dead and putrid carcaſes were, one would think, a ſhocking and odious employment, yet ſome anatomiſts dote upon it: and, I muſt own, its uſefulneſs has greatly enamour'd me with diſſection. For although the fine works of artificers ſeldom fail to draw the curious and raiſe their wonder; and though, in my travels, I have often, with difficulty, purchaſed the ſight of a maſter-piece of art; yet, at preſent, a ſkilful diſſection wou'd pleaſe me better than the famous clock at *Straſburgh*. So that *Ariſtotle*, in my opinion, acts like a true philoſopher, when dropping the conſideration of the ſublimeſt natural productions, he deſcends to record the homely hiſtory of animals: "We come now, "ſays he, to the nature of animals, with a reſolution to comprize all we can, "be it baſe or noble."

Philoſophy, whilſt it gratifies, does not diſguſt the mind; but is an employment worthy of it.

'Tis a farther recommendation of natural philoſophy, that the truths it teaches highly gratify without the leaſt diſguſting the mind; being ſuch as conſcience never upbraids us with in the enjoyment, nor turns to torments afterwards. Neither are theſe truths obtain'd by that low kind of employment which, tho' not condemn'd by religion, cannot ſtand the teſt of reaſon; for even the moſt rational and ſtrictly virtuous men have employ'd themſelves herein. *Pythagoras*, *Democritus*, *Plato*, with numberleſs others, fam'd for wiſdom, thought philoſophy demanded not only their ſtudies at home, but travelling to the eaſtern countries, where it was beſt taught, in order to obtain. And that rigid teacher *Seneca*, not content thro' his other writings frequently to extol the contemplation of *nature*, left us ſeven books upon the ſubject.

How far religion countenances this purſuit, we ſhall ſee hereafter; but reaſon tells us 'tis worthy of a rational creature: ſince thoſe who have advanced reaſon to the greateſt height, have been herein moſt ſtudiouſly engaged. Nay, this noble faculty, conſcious of its own abilities, upon due application, is affronted when not thus conſiderably employ'd; whilſt we become guilty of our own degradation, who being furniſhed and placed, as we find our ſelves, regard this vaſt and inſtructive univerſe, the nobleſt part whereof we are deſigned to make, as ſlightly as ſuch animals to whom lower faculties and prerogatives are aſſign'd. *Ariſtotle* well obſerves, that "Man is the only animal of an erect ſtature, and "that becauſe his nature participates of ſomething divine; the properties where-"of are underſtanding and wiſdom." And certainly, it ill ſuits the dignity of ſuch a creature to live in ignorance of the laws of that great common-wealth, the world, whereof he is the moſt eminent member. Nay, as it is injurious, ſo, did not cuſtom or ſenſuality ſtupify us, it muſt alſo be afflicting to a rational mind, not to underſtand the ſtructure and contrivance of the body wherein it reſides, and by means whereof it acquires all the knowledge it has.

Indeed, the generality of men, how indolent ſoever, come by the ſuperiority of their faculties, which enables them to reflect, in ſome degree, to know more than brutes; but, if contented with the firſt appearances of things, we rely upon our nature, without the help of induſtry, we wilfully loſe the nobleſt

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uſe and higheſt ſatisfaction of our reaſon; and whoever is thus wanting to himſelf, may be ſaid to lead the life of a ſpider in a palace, who takes notice of nothing there but what paſſes in her own web.

To give the greater ſanction to philoſophy, it may be obſerv'd, that according to *Joſephus*, *Seth* and his poſterity ſtiled the Sons of God, firſt cultivated aſtronomy. It was a general tradition, that *Abraham* firſt inſtructed the *Egyptians* both in aſtronomy and philoſophy; and *Beroſus*, as cited by *Joſephus*, records him to have been ſkill'd in the ſcience of the ſtars. And ſpeaking ſoon after of *Abraham* and the *Egyptians*, 'tis ſaid expreſly, "that he ingenuouſly communi-"cated to them the ſciences of arithmetic and aſtronomy; for the *Egyptians* "knew nothing of either, before he came among them."

But to put it beyond queſtion, that the greateſt genius need not bluſh at the ſtudy of natural philoſophy, *Solomon* himſelf not only cultivated, but taught it, and left behind him writings on that head, from whence, if ſome Rabbies ſay true, *Ariſtotle* borrowed moſt of his choice pieces; tho' the originals deſcended no lower, leſt, ſay the Rabbi's, they ſhould have been idoliz'd, or all kind of debauchery committed, in hopes that the diſeaſes conſequent thereon, might thence have been eaſily remedied.

The variety of nature excites our inquiry.

From the entertaining variety of nature's works, we are again inſtigated to their contemplation; for whilſt moſt other ſciences are ſo limited, that one of the beſt ſyſtems thereof will uſually contain all that is known upon each head; the objects of natural philoſophy, being as numerous as the laws and works of nature, are ſo various, that the age of *Methuſelah* would fail before the ſubject. Nay, ſo fertile is each particular object of a naturaliſt's contemplation, that ſeveral might be named, to diſcover all the uſeful properties but of any one in the number whereof, a ſingle life wou'd be ſufficient. 'Tis almoſt incredible what variety of vegetables the earth produces: botaniſts have, long ago, enumerated ſix thouſand; and many more have been ſince diſcovered. I lately had a peculiar and excellent kind of pepper ſent me from *Jamaica*, the ſhell whereof taſtes like cinnamon, but ſmells like cloves; a vegetable unknown to the botaniſts of our country. Whole treatiſes, however, have appear'd upon ſingle plants. *Themiſon*, according to *Pliny*, publiſhed a volume upon plantain; *Amphilochus* one upon trefoil and hadder; and king *Juba* another about a ſpecies of water-lilly. To come to later times, *Carolus Roſenbergius* wrote a book upon Roſes, and *Martinus Blochwitius* one about elder. Among the chymiſts *Angelus Sala* publiſh'd ſeparate treatiſes of vitriol, tartar, and ſugar. *Untzerus* too, wrote particular tracts upon mercury, ſulphur, and ſalt; as did alſo *Paracelſus* upon St. *John*'s-wort, arſmart, hellebore, and ſome other plants. *Baſil Valentine*, a candid chymiſt, publiſh'd an excellent treatiſe of antimony, which was afterwards improved upon by *Angelus Sala*; nor were there wanting many other uſeful treatiſes on the ſame ſubject, to confirm *Baſil Valentine*'s ſaying, "'Tis impoſſible for one man to "diſcover all that is diſcoverable in antimony." As a farther confirmation whereof, I, my ſelf, lately directed the drawing of an actual quickſilver of antimony, very different from any I had before met with. I have, likewiſe, a peculiar way of ſeparating from this drug a combuſtible body that is ſcarce diſtinguiſhable from common brimſtone; and gain a menſtruum by diſtilling *French* verdi-

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verdigreaſe in a ſtrong, naked fire, which makes a blood-red tincture of the glaſs of antimony much more expeditiouſly than that uſed by *Valentine* and his followers. This menſtrum alſo being drawn off, leaves a calx that will yield a red tincture with ſpirit of wine.

When chymiſts expoſe ſeveral conſiſtent, but not fixed bodies to the action of the fire, they uſually do it in veſſels, either open, as when they make calx, or glaſs of antimony, or, at leaſt, in ſuch as are not ſo cloſe, but that air is included with the matter; and tho' they regard not this included air, becauſe uſually there is not much of it in the veſſel, yet it may have a conſiderable influence on the effects of the fire; not only as it contributes to the aſcent and ſuſtentation of the diſſipated parts of the mineral, but as it affords theſe corpuſcles opportunity to fly about in it, and thereby to make aſſociations or coalitions and concretions that otherwiſe would not be produc'd. Upon this account, it may often be of uſe to employ a method, to ſecure the body expos'd to the action of the fire, from the contact of the air; whereby the parts of the body, and perhaps the igneous corpuſcles, will be reduced to act reciprocally upon one another, without cauſing any conſiderable diſſipation, or avolation of parts.

To apply this to antimony, we take of that mineral well powder'd, and of white chalk well dry'd, reduc'd likewiſe to powder; with theſe in a large earthen pot or crucible, we make ſeveral layers, leaving the lower and uppermoſt bed of chalk, and the laſt thicker than any of the reſt; and taking care that none of the layers of antimony are too thick, that the heat may penetrate them the better; we cover the veſſel, put it among the kindled coals of a digeſtive furnace, and there keep it for a competent time; which, according to the bigneſs of the pot and the ſtrength of the fire, may be a day and a half, and ſometimes above two days.

But to proceed, the learned *Kircher* has given us a *folio* volume of light and ſhadows, and a *quarto* upon the load-ſtone; yet our *Gilbert*, and ſince him *Cabeus* wrote on the ſame ſubject; which tho' *Kircher* has more lately proſecuted in a voluminous work, I am of opinion there's room enough left for farther improvement; having my ſelf very lately made a remarkable experiment with that wonderful ſtone.

Even the ſmalleſt productions of nature may ſolicit and reward our enquiries. *Pliny* treating of inſects, is tranſported with admiration at the workmanſhip ſhewn in them: "The contrivance of nature, ſays he, is no where more conſpicuous or more viſibly collected than in theſe minute creatures." And after this he handſomely admoniſhes his reader, that no ſubject of natural knowledge is contemptible or ſuperfluous. From conſidering the ſkin on the ſole of the foot, *Galen* admired the wiſdom of God; and he excellently ſaid, "tho' ſome creatures "ſeem made of coarſer materials than others, yet the maker's art ſhines through "the deſpicableneſs of the vileſt matter: the ignorant indeed, admire the beauty "of the materials, but artiſts are ſtruck with the workmanſhip of things." And *Ariſtotle* coming to treat of the parts of animals, prevents his reader from thinking the meanneſs of the ſubject ſhould render it deſpicable. Nay, the haughty *Paracelſus* condeſcended to write a book about the myſteries of worms, wherein he juſtly reprehends the lazineſs and pride of thoſe phyſicians "who neglect and contemn

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" all inquiries into nature, and receive the fruits thereof from others with ſcorn " and deriſion," he adds, "God has created nothing ſo vile or deſpicable that may " not turn to the uſe of man." And certainly whatever God has thought fit to make, we ſhould not think unworthy to know; for a human mind cannot be debaſed by a notion of what was form'd according to a divine idea: and therefore *Solomon* treated as well of reptils as of nobler animals, as well of the ezob on the wall as the cedars of *Lebanon*. And durſt I propoſe my own actions for examples, I ſhou'd ſay, tho' my condition, God be praiſed, enables me to make experiments by other hands, yet have I never refus'd to diſſect any kind of animals, nor in my laboratory to handle lute and charcoal.

Philoſophy gives us the command of nature.

But farther, philoſophy is not only delightful as it brings us acquainted with nature, but alſo as it often inſtructs us to command her; for the naturaliſt knows many things of which others are ignorant, and performs what they cannot; becauſe he not only underſtands, but in ſome meaſure, imitates, multiplies and improves ſeveral of her extraordinary works. And how naturally we affect the uſe of this power may be ſeen in children, who from a ſeeming innate propenſity, delight in endeavouring to change the productions of nature. And ſo extenſive is the naturaliſt's power, tho' he cannot produce one atom of matter, that he can introduce numberleſs forms, and work ſurprizing changes among bodies: ſo that were *Adam* to revive and ſurvey that vaſt variety of man's productions to be found in our ſhops and magazines, he would admire to ſee what a new world had, by the induſtry of his poſterity, been added to the old one.

'Tis true, indeed, man is but the miniſter of nature, and does no more than apply agents to patients, yet by his ſkill in ſuch application he gains dominion over creatures otherwiſe much ſtonger than himſelf; and can even perform ſuch things, as to another man ſhall appear aſtoniſhing. Thus the poor *Indians* thought the *Spaniards* more than men, becauſe their knowledge of gun-powder enabled them to thunder and lighten deſtructively. And this empire of man over the creatures may to a ſound philoſophical mind prove more ſatisfactory than that for which bloody conteſts frequently ariſe; for the latter being only a gift of nature, or a preſent of fortune, and often the purchaſe of crimes, argues no real ſuperiority in the poſſeſſor; but the latter is a power becoming man as man. Perhaps alſo, the ſurprizing things perform'd by an ingenious man gives him a higher ſatisfaction as being proofs of his knowledge, than as they are inſtances of his power or means of increaſing his wealth.

SECT. II.

Whether philoſophy leads to atheiſm.

ANother advantage of philoſophy, we ſaid, was the raiſing and cheriſhing our devotion. But many eminent divines, it ſeems, out of an holy jealouſy for religion, repreſent this ſtudy as unbecoming a chriſtian, and leading to

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to atheiſm; "becauſe, ſay they, by enabling men to account for all ſur-"prizing appearances from ſecond cauſes, it brings them to diſbelieve a firſt;" which objection, were it well grounded, wou'd cauſe me to condemn what I am now recommending: for I had much rather have men chriſtians, and ignorant of nature's myſteries, than philoſophers, and deny the author of nature. Now, tho' a well-meant zeal may defend the perſons of theſe gentlemen; yet their doctrine has too bad a tendency to be left unanſwer'd. But not to mix too much divinity with a philoſophical diſcourſe, I ſhall here only give the heads of a reply.

Two principal deſigns of God in creating the World.

And firſt, tho' it were preſumption in man, "who is but of yeſterday," to pretend to aſſign all the ends of God in the work of creation; yet ſurely it may humbly be ſuppoſed, that two principal deſigns of his creating this ſyſtem, were the manifeſtation of his own glory and the good of mankind; becauſe ſacred writ, in abundance of paſſages, aſſures us of the former; not to mention heathen authorities. And that none of God's works might want intelligent ſpectators, tho' man was not formed till the ſixth day, the angels, as 'tis generally ſuppoſed, were created on the firſt. The other deſign appears from the time of man's creation, which was kindly deferred till all things were prepared for his reception; from the commiſſion given him "to repleniſh the earth and ſubdue it;" by the placing of noble luminaries "to give light upon the earth, and divide between the day and "the night;" the ſame is alſo farther confirmed by other texts of ſcripture. And accordingly God cauſed the ſun to ſtand ſtill at one time, to go back at another, and has frequently either ſuſpended or alter'd the laws of other parts of the univerſe, for the inſtruction, or benefit of man. On the other hand, upon *Adam*'s tranſgreſſion the ground was immediately "curſed for his ſake;" even the face of the earth was deſtroy'd for the ſins of *Sodom*; and the other animals as well as men periſhed, in the deluge. So alſo "in the laſt days, when the earth ſhall be repleniſhed with ſcoffers," unexpected flames will either deſtroy or transform the world.

The ſame is evident alſo from reaſon; for as in this viſible world, man alone is capable of enjoying many of the other creatures; and of diſcerning the excellence of the Creator in them; 'tis plain they were made for man. 'Tis not for themſelves that rubies flame or diamonds ſparkle; that bezoar is antidotal, or that trees are yearly exhauſted in profuſion. That light the ſun around diffuſes, is uſeleſs to himſelf, an inanimate Being; but entitles him miniſter to the ſyſtem. Animals alone, among the creatures, have a ſenſe of their own exiſtence, and of theſe, only man acknowledges all the reſt to be the gift of God, and glorifies him for them; a truth acknowledg'd by *Chriſtians*, *Jews*, and *Heathens*. The inference I wou'd make from all which is, that, whoever deters men from ſtudying nature; wou'd fruſtrate God of the above-mentioned ends of creation. For beſides that the corporeal delight and advantage we are capable of receiving, muſt be greatly obſtructed thro' ignorance of natural philoſophy, as will hereafter be made evident; our ſpiritual happineſs depending upon religion, the greateſt benefit we can receive from the things of this world, is their increaſing and cheriſhing this grand principle, and thereby rendering us acceptable to

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God; and both theſe effects they were, doubtleſs, deſign'd to have on us. For to ſuppoſe innumerable creatures ſent into the world only to feed and pleaſe mankind, but not to afford them any inſtruction, is like imagining a prudent merchant would furniſh his friends with numberleſs curioſities and neceſſaries for a voyage, without allowing them the uſe of a ſea-chart or compaſs.

Moreover, God himſelf lays us almoſt under a neceſſity of enquiring into his works. The book of *Geneſis* begins with a deſcriprion thereof, and deſcends to a detail of each day's proceedings in the creation; and tho' the ſcripture uſually condeſcends to the conceptions of the vulgar, yet the two firſt chapters of *Geneſis* perhaps afford finer hints of natural philoſophy than men are hitherto apprized of *. Beſide, there are many texts in ſacred writ unintelligible without a previous knowledge in natural philoſophy. Many paſſages therein allude to the properties of animals, as that precept of our Saviour, "be ye wiſe as ſerpents and harmleſs as doves." And ſo neceſſary has natural knowledge been thought to illuſtrate texts in ſcripture, that abundance of learned men have publiſhed whole treatiſes of the animals, ſtones, and other works of nature mentioned in that book. Nor ſhou'd the theme be diſcontinued, for there remain many paſſages of it not to be underſtood without penetrating deep into nature's myſteries.

The attributes of God manifeſt in his creatures.

But to come to the attributes of God, manifeſted in his creatures; the moſt conſpicuous are his power, his wiſdom and his goodneſs; and the ſame may alſo, tho' differently and more obſcurely, be found in the Bible. How eminently is the firſt of theſe diſplay'd in making all things out of nothing; and, without materials, raiſing this immenſe fabric, whoſe dimenſions are ſo prodigious, that even a mathematical demonſtration can hardly render them credible? To paſs by elephants and whales, mountains and ſeas, as inconſiderable objects, the globe we inha-

* Theſe hints ſeem to have been well conſidered and employ'd by the Rev. Mr. *Whiſton*, who, from them and the *Newtonian* ſyſtem of philoſophy, has nobly attempted to give a rational and philoſophical account of the creation, in agreement with the *Moſaic* hiſtory of it. This author firſt ſuppoſes that the *Moſaic* creation is a bare hiſtorical narrative of nothing but the formation of the earth out of a chaos, and of the ſucceſſive viſible changes, each day made therein, till it became a fit habitation for mankind; and that this hiſtory is to be underſtood in the obvious literal ſenſe, unleſs where an evident reaſon can be given for the contrary. He then proceeds to ſhew, that the rudiments of the earth were the atmoſphere of a comet; that the annual motion of the earth commenced at the beginning of the *Moſaic* creation, but its diurnal rotation not till after the fall of man; that the orbit of the earth was a perfect circle before the deluge; that all the ſmall bodies which compoſe the earth, being originally in a mixed confuſed fluid ſtate, were the chaos; that the upper regions thereof, before the beginning of the *Moſaic* creation, were involved in a thick darkneſs, which diſſipated, by degrees, as the parts of the chaos ſubſided, according to their ſpecific gravity. The firſt day's work was according to our author the production of light, or the ſucceſſive arrival of ſome of the ſun's rays to all the parts of the earth; on the ſecond day the air with its vapour was elevated and ſpread out above the earth; on the third the inferiour waters were collected into ſeas, whence the dry land appear'd with its vegetable productions, the vapour in the air being ſufficiently rarify'd: on the fourth the celeſtial bodies became viſible. And now the terraqueous globe being habitable, fiſh and fowl were produced on the fifth day, land-animals on the ſixth; and laſtly man. But Mr. *Whiſton* will not allow the earth to be ſo haſty a production as is uſually ſuppoſed; for he endeavours to ſhew, that as at firſt, it had no diurnal rotation; ſo what *Moſes* calls days were in reality years. The reader, who deſires farther ſatisfaction, may conſult the ſecond edition of Mr. *Whiſton's New Theory of the Earth.*

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bit, though by the common computation, no leſs than 22,600 *Italian* miles in circumference, is but a point compared to the firmament; as we learn from the parallax of the fix'd ſtars. And according to *Ptolemy*, the ſun is not only 166 times bigger than the earth, tho' the diſtance between them be 1165 of the earth's ſemidiameters; that is, by *Gaſſendus*'s computation, ſo many times 4177 miles; but alſo that the ſmalleſt fix'd ſtars are conjectured to be 18, and the largeſt 108 times bigger than the earth. The *Copernicans* carry their computations higher, for *Philippus Lanſbergius* ſuppoſes the earth's orbit, the ſemidiameter whereof is computed 1500 times bigger than the earth's, to be but a point in regard of the fix'd ſtars, which he takes to be removed from the earth 42,000,000 of its ſemidiameters, or 175,434,000,000 miles; a ſurprizing diſtance * ! And tho' we allow for inaccuracies, and the differences of obſervations, whence ſuch computations are made; yet as the fix'd ſtars are perhaps placed ſuch different diſtances from the earth, that tho' they appear different, yet they may all be equal in magnitude, the earth can be but a point in reſpect to the heavens.

His wiſdom. The next attribute of God, his wiſdom, ſhines ſo ſtrongly in his creatures, that an intelligent ſpectator, conſidering them in any determin'd view, cannot fail to diſcover it. So endleſs a multitude and variety of birds, beaſts, fiſhes, reptils, herbs, ſhrubs, trees, ſtones, metals, minerals, ſtars, *&c.* each whereof is perfectly enabled to anſwer the ends of its creation, beſpeak a wiſdom infinite, and extort the exclamation of the *Pſalmiſt*, "How manifold are thy "works, O Lord; in wiſdom haſt thou made them all." And how highly ſoever ſome naturaliſts may value themſelves, yet the utmoſt they can do, is to underſtand and applaud, without rivalling, the works of the Almighty. For as a novice, when a curious watch is taken to pieces before him, may diſcern the excellence of the contrivance, without being able to make ſo artificial a machine; ſo the anatomiſt, by frequent diſſections, learns the admirable ſtructure and uſe of the parts of a human body, tho' he cou'd not before deviſe how all the animal functions might ſo well be perform'd.

Thus, late experiments having ſhewn the uſe of the blood's circulation, and of the valves in the heart and veins, (which the famous Dr. *Harvey* told me, gave him the firſt hint of his grand diſcovery) we at length acknowledge the wiſdom of the contrivance, after it had eſcaped the ſearch of many preceding ages.

* In the year 1720. M. *Caſſini*, by the command of the King of *France*, exactly meaſured ſeven degrees and a half on the earth's ſurface, whereby he found, ſuppoſing the earth to be a ſphere, one degree to contain 343,752 *French* feet; which agrees as exactly as cou'd well be expected with the former menſuration made by M. *Picart*, whereby there are allow'd 342,360 feet to a degree; and with that of Mr. *Norwood*, which aſſigns 367,196 *Engliſh* feet to the ſame. Hence the circumference is 123,750,720 *French* feet; and ſuppoſing the earth ſphere, its diameter 39,391,077 feet. But the earth being higher at the equator than at the poles, Sir *Iſaac Newton* makes its greateſt ſemidiameter 19,767,630, and its leaſt 19,609,820 *French* feet. The proportion of the *Engliſh* foot to the *French*, is nearly as fifteen to ſixteen. See *Newton Princip. Edit.* 2. p. 378,387. *Memoir. de l'Acad. Roy. Ed. Amſt.* A. 1701. The diſtance of the earth from the ſun is now computed at 81,000,000 miles; and the modern aſtronomers allow the ſun to be in magnitude 900,000, and in quantity of matter 230,000 times bigger than the earth. The fixed ſtars are each ſuppoſed the ſun of a ſyſtem like this of ours; and ſuppoſing their parallax 45", to be diſtant from the ſun, about 700,000,000,000 miles. See *Huygen. Coſmoth.* p. 14. 135. *Newton, Princip.* p. 482. and *Philoſoph. Tranſact.* N°. 209. p. 101.

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And tho' God's greater works declare his great power and wiſdom, yet the latter is no leſs manifeſt even in the ſmalleſt creatures. For, as the skilful *Protagoras*, by the extreme neatneſs and almoſt undiſcernible fineneſs of a ſtroke, diſcover'd it to come from the hand of *Apelles*; ſo God in theſe minute creatures often draws traces of omniſcience too delicate to be aſcribed to any other cauſe. Elephants to me appear leſs admirable than moles, whoſe eyes are manifeſtly deſign'd to ſee only the light, not other objects, by its means; and whoſe feet are adapted to dig themſelves a way under ground. And however meanly the vulgar may think of ſome minute creatures, my curioſity, I own, determines me to the ſmaller kind. A gentleman, return'd from *Jamaica*, told me he had ſeen in that iſland a great number of trees, which bear the ſilk-cotton, and found many of them to ſurpaſs, in bulk and height, the larger ſort of our *Engliſh* oaks; and that on a mountain, which many, out of curioſity, went to viſit, he ſaw a ſtupendous ſilk-cotton tree, that was twenty one yards circumference in the body. The ſame perſon aſſured me he ſaw a cannow made of the hollow trunk of one of theſe trees, which, after all that had been taken off to give it the ſhape of a veſſel fit for ſervice, was thirty feet about, and of a proportionable length. But the humble ſenſitive plant and abject load-ſtone, delight me more than lofty oaks or monſtrous rocks. An ant-hill has given me more pleaſure than the *Alps*; which leſſens my admiration, that the ant was an object of *Solomon*'s contemplation. The ſilk-worm raiſes my wonder more than thoſe outlandiſh monſters, which multitudes flock and pay to ſee. 'Tis true, ſeas and mountains, with other immenſe productions of nature, proclaim God's power; but the curious contrivance of ſome animals, ſo ſmall, that they ſeem all workmanſhip, demonſtrates his wiſdom no leſs than thoſe; ſo that not only "his greatneſs, but "alſo his underſtanding is unſearchable." Add to this, the inconceivable variety there is of animals, in whoſe contrivance the great Former of all things has diſplay'd an almoſt equal ſkill. Such reports are given us of the immenſe bulk of elephants, that they ſeem incredible. *Gaſſendus* tells us of one in the year 1631 that weigh'd near 5000 *Roman* pounds, of twelve ounces each; which appears probable from the bigneſs of ſome elephants teeth; one of which, according to *Linſchoten*, will weigh 200 pounds, tho' each pound conſiſt of twenty four ounces. On the other hand, not to mention that animal, bred in wax, ſuppoſed by *Ariſtotle* the leaſt in nature; compare a cheeſe-mite of near a grain in weight, tho' ſeveral together will ſcarce equal that, to the ſmall elephant abovemention'd, and you'll find him exceed the mite near 28,800,000 times. Notwithſtanding this, the limbs, and even the hairs growing on the legs of this minute creature, have thro' a microſcope appear'd diſtinctly to my ſelf and others. Conſider now, what delicate ſkill it requires to contract into ſo ſmall a compaſs the numerous parts of this little creature; to aſſign the proper number of them to its eyes and other organs of ſenſe; to its head, ſtomach, and inteſtines, *&c.* and how exceeding ſubtile that nervous fluid muſt be which moves ſuch little limbs. But farther ſtill; as we have found theſe ſmall creatures to be hatch'd from eggs, if the proceſs imitates that of chickens, how very minute muſt be their recently animated parts; for in the eggs of hens, I have ſeen the limbs of the live chick clearly

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clearly delineated, whilst it kept so close between the white and the yolk, where 'tis generated, that they both appear'd entire, and included in their respective membranes. 'Tis surprizing what vastly disproportionate masses of matter God has form'd into living creatures. To pass by other accounts of whales, *Jo. Faber Lynceus* saw, in the year 1624, a dead one, thrown up near *Santa Severa*, about thirty miles from *Rome*, that measured ninety one palms in length, and fifty in thickness; with a mouth capable of admitting a man on horseback, and a tongue the length of twenty palms. He adds, that four years before this, there was another thrown on the island *Corsica*, near the coast of *Italy*, an hundred feet long, big with a cub of thirty feet, that weigh'd 1500 pounds. But to shew the disproportion between this kind of fish and common elephants, "the solid fat, alone, of the whale weigh'd, says our au- "thor, 135,000 pounds," that is, twenty seven times more than the whole elephant mention'd by *Gassendus*. And as the creator has made fish of such an enormous size, that the ocean seems only a suitable pond for them; he has also framed others that live in fluids, so inconceivably small, that many thousands of 'em will not amount to a grain in weight. For by the help of a good microscope, comparing one of those creatures found in vinegar, with a cheese-mite, we thought the fish almost as slender as one of the legs of the mite. Considering, therefore, what a vast quantity of matter the creator can fashion into a whale, and in how little compass he can contrive all the parts that constitute a fish, we must say with the *Psalmist*, "there is none like unto thee, "O Lord, neither are there any works like unto thy works."

His goodness.

The third attribute of God manifested in the creation, is his goodness; whereof every creature partakes, both in its first existence, and preservation of its state, *till* some higher end calls for its dissolution. But this goodness is chiefly conspicuous in animals, who, tho' some of 'em don't more acknowledge, are yet more capable of enjoying his bounty, than inanimate beings. For, omitting that God, in scripture, is stiled, "the preserver both of man and beast;" and that he is said "to give food to the young ravens," what excellent provisions are made to continue the various and numberless species of living creatures? In a more particular manner does the goodness of God appear towards man, whom he has honoured with his image, and placed over most other visible creatures, which either by his superior power or knowledge, are render'd serviceable to him; even the vast celestial bodies, tho' immensely distant from us, are, by mathematical skill, brought to serve our purposes; as to measure time, and shew the longitudes of places. The stars afford us light; we breathe the air, and receive the benefits of fire both in the kitchen and the laboratory: the earth supports our buildings, the clouds water our land, the sea and winds convey our ships to remotest regions, and return them fraught with all the choicest productions of art and nature; beasts innumerable are destin'd to feed, to cloath and carry us; flowers and jewels to delight and adorn us; fruits to sustain and refresh us; stones and timber to lodge us, and simples to cure our diseases; in a word, the whole world is only our magazine; and nature seems wholly employ'd to accommodate and delight us. For, perhaps, there's not a plant or animal, a metal or a mineral, of all that infinite number we possess, how despicable soever it may seem, which might not,

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by a knowledge of its nature, become ſerviceable to man. The ſparkling diamond yields in virtue to the dull load-ſtone, that author of commerce to many regions of the world; the lion, the eagle, and the whale are, together, leſs uſeful than that mean inſect the ſilk-worm. And to regard the intrinſic value of things, and their medicinal virtues, doubtleſs, we trample upon many, that, did we know their uſes, might ſerve the nobleſt ends. For certainly, all the properties of concretes, and virtues of common ſimples are not hitherto known; ſince new diſcoveries are daily made herein. What a large collection of this kind does *America* afford us? "Many excellent trees "and ſhrubs, ſays *Piſo*, beſides plants without number, are here uſually "very different in their form, leaves and fruits from thoſe of the old world: "and the ſame holds good of birds, beaſts, fiſh and inſects." And to give a ſignal inſtance of the latent powers in *American* ſimples; how very effectual has the *Peruvian* bark been lately found both at *Rome* and *London* againſt quartan agues? For tho' this medicine be depreciated by ſome, as being rather palliative than curative; yet according to Sir *Kenelm Digby*, 'tis ſo thro' the patient's rather than the phyſician's fault; for he ſolemnly aſſured me, that of between twenty and thirty perſons, whom he cured of quartans by this remedy, not two relapſed. Nor can it be queſtion'd that we have unknown plants of extraordinary efficacy at home. I my ſelf have often gather'd an unpromiſing plant, called rue-leaved whitlow-graſs, which ſlightly infuſed in beer, to my knowledge, lately, without pain, and in few days, cured a kinſman of Sir *Kenelm Digby*'s of the king's-evil; yet I don't find any botaniſt recommend it for that diſtemper. But this bounty of God to man ſeems abated, 'tis ſaid, by permitting ſome poiſons. To this it may be replied, that many poiſonous bodies contain their own antidotes; and according to *Piſo*, "'tis "hard to ſay, which of the two moſt abound in *Braſil*. For as the principal "poiſons here, are the leaves, flowers, and fruits of the plants *Tangarac* "and *Juquer*, each has its own root for an antidote; and the natives ſucceſs-"fully apply the fat and heads of vipers to venomous wounds, or an arti-"ficial preparation of the whole bodies of the creatures that gave them." Beſides, 'tis probable that human art might reduce all ſuch bodies into uſeful medicines: at leaſt, the advantages already gain'd by a proper management of antimony and quick-ſilver may encourage us to hope ſo. Opium is by phyſicians rank'd among poiſons, yet it affords ſuch remedies as they would be ſorry to want. Oil of ſcorpions is not only an antidote for the ſting of that creature, but is alſo good in other caſes. To give only one inſtance more, the root *Mandiboca*, common throughout the *Weſt-Indies*, which tho' of it ſelf it be deadly poiſon, is one of the moſt uſeful things that country produces; for by an eaſy preparation, it affords not only many populous nations their bread, which from its taſte, and colour I judge good; and to ſome of them no ſmall part of their drink; but an antidote alſo.

What farther manifeſts God's goodneſs to man is, that the creatures not only delight and accommodate, but alſo ſerve to inſtruct him; for nature every where lays leſſons before us; which if we diſregard, we loſe the great benefit deſign'd to our nobler part, the ſoul. "We ſhou'd not, ſays St. *Auſtin*, uſe our eyes, "like brutes, to provide for the belly, not the mind; but as men, to behold "the

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" the heavens, and the work of nature, and thence diſcover their author."

Laſtly, the creatures not only demonſtrate the being and attributes of God, but likewiſe remind us of our duty; for God informs us hereof no leſs by his works, than his word; thus the rain-bow, for inſtance, was deſigned to ſhew his goodneſs to all nations, and prevent their expecting a ſecond deluge. 'Twas a truly great ſaying of *Plato*, " The world is God's epiſtle " to mankind;" for God accordingly, by *Solomon*, ſends the ſluggard to learn induſtry of the ant; and *Chriſt* commands his diſciples to learn prudence and inoffenſiveneſs from ſerpents and doves; he bids them alſo conſider the lillies in the field, in order to acquire a firm reliance upon God. St. *Paul* rebuking the *Corinthians* for their weak Faith as to the reſurrection, bids them reflect on the ſowing of corn; and the *Pſalmiſt* grows humble by contemplating the higheſt works of nature: " When I conſider, " ſays he, the heavens, the work of thy fingers, the moon and ſtars " which thou haſt ordain'd, what is man that thou viſiteſt him?" Hence it appears, that God deſigned the world not only as a palace for men to reſide in, but alſo for a ſchool of virtue to bring them to eternal felicity.

SECT. III.

HAving ſhewn how greatly the ſtudy of nature promotes both the temporal and ſpiritual welfare of mankind; let us next conſider whether a ſtop put to natural inquiries would not tend to deprive God of the glory that is due to him. And certainly, we can never praiſe and admire him for thoſe works which we think it pernicious or dangerous to conſider. But the works of God are not like pompous pageants, or the tricks of juglers, where concealment is requiſite to wonder: our admiration always riſes here in proportion to our knowledge; becauſe the farther we contemplate, the more ſigns we diſcover of the author's perfection: and even our utmoſt ſcrutiny can give us but a faint veneration of his omniſcience. For, however obvious his exiſtence appears, it requires a cloſe and philoſophical conſideration to ſhew he has diſplay'd in the creatures a power, wiſdom and goodneſs worthy of himſelf. What different ideas of his wiſdom riſe from the conſideration of eggs to a naturaliſt, who has traced the cicatricula to the formation of the chick; and one who only knows their common uſe? As God therefore, delights to be honoured in all our faculties, and conſequently in that of reaſon, as well as faith, there will appear an immenſe difference between that general, confuſed, and indolent idea we uſually frame of his power and wiſdom, and thoſe diſtinct, rational and affecting ones of his attributes, which may be gained by an attentive inſpection of the creatures that were chiefly made for this very purpoſe. The queen of *Sheba* had, in her own country, conceived very highly of *Solomon*'s wiſdom, yet ſhe undertook a journey to become an eye-witneſs of its effects; and finding them infinitely to ſurpaſs what fame had related, confeſs'd it in a pathetic extacy.

Whether a ſtop put to natural inquiries would not deprive God of the glory due to him.

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Admirable is the ſaying of *Hermes Triſmegiſtus* to his ſon, "There is "no religion more juſt than to know the things that are, and to return "thanks for all things to him that made them. Be pious and religious, O "my child, for that is the beſt and higheſt philoſophy." And, perhaps, our more numerous wants and appetites were deſign'd to ſpur us on to ſcrutinize and ranſack nature, that ſo we might make larger diſcoveries of the omniſcient author, than other creatures.

To illuſtrate this point the farther, we may remember that philoſophers have almoſt univerſally conſider'd the world as a temple: not only *Plutarch*, *Cicero*, and *Seneca*, but *Philo* the *Jew* is expreſs to this purpoſe. As for *Chriſtian* philoſophers, it were endleſs to cite them upon this head; and even the ſcripture itſelf uſes the ſame figure of ſpeech. Suppoſing then, the world to be a temple, I would infer that man is the prieſt to officiate therein; and conſequently bound, as being the head creature here, to return thanks and praiſes to his maker, both for himſelf and the whole creation. And ſurely 'tis very unbecoming, that God's mercy alone, becauſe moſt beneficial to us, ſhou'd engroſs all our thoughts, whilſt his power and wiſdom, attributes equal to the former, becauſe all of them are infinite, remain neglected; tho' theſe commanded the adoration both of man and angels, before ſin occaſioned the exerciſe of the other. For my own part, I dare not thus limit my devotion, tho' I wou'd not undervalue the meaneſt act thereof that ſtands recommended either by ſcripture or reaſon: ſtill I muſt think that God is acceptably, and, perhaps, more nobly, ſerved by conceiving high, rational and manly notions, with a ſuitable adoration, of thoſe divine attributes for manifeſtation whereof this vaſt fabric was erected.

From hence, methinks 'tis plain, that to hinder the progreſs of natural knowledge detracts from God's glory as well as obſtructs man's felicity. I will, however, go a ſtep farther, to ſhew that neither reaſon, ſcripture, nor experience can countenance ſuch an attempt.

And firſt, did the author of nature know that the contemplation of his works led to a diſbelief of his being and attributes, he wou'd, ſurely, never have invited and preſſed mankind thereto ſo ſtrongly as we ſee he does; for beſides the ſollicitations already mention'd, the ſabbath ſeems originally inſtituted to commemorate the creation, and give men a frequent opportunity to contemplate God in his works. And the primitive *Chriſtians*, accordingly, celebrated as well the creation on the ſaturday, as the redemption on the ſunday; which practice, tho' the weſtern churches have long ſince dropp'd, is, I am inform'd, ſtill retain'd in many of the eaſtern. Moreover, whoever ſhall duly conſider the bible, particularly the books of *Job* and the *Pſalms*, will find a greater harmony between philoſophy and divinity, than our opponents imagine. St. *Paul* tells us, "the inviſible things of God, from the "creation of the world are clearly ſeen; being underſtood by the things that "are made, even his eternal power and god-head." Nay, ſo far is the ſtudy of nature from leading to atheiſm, that *Job* expreſly ſays, "Ask now the "beaſts and they will teach thee, and the fowls of the air, and they will tell thee; "or ſpeak to the earth, and it ſhall teach thee, and the fiſhes of the ſea ſhall "declare unto thee. Who knoweth not that in all theſe things the hand of "the

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"the Lord hath wrought this?" And agreeably hereto moſt of the moral writers, and ſuch as labour to demonſtrate the truth of the chriſtian religion, undertake to prove the being of a God, from the conſideration of the univerſe, and that he is the author thereof *.

But as philoſophy, you ſay, leads men to atheiſm, by enabling them to account for the phenomena of nature from ſecond cauſes, it will be hard to ſhew how, upon this ſuppoſition, it can do ſo; becauſe we are in no wiſe able to explain all appearances by any principles whatever. And truly, not only the generation of animals remains a myſtery, but, even to explain and adjuſt all the phenomena of that apparently homogeneous body, mercury, has hitherto proved ſo difficult, that, for ought I know, it may ſtill continue inſuperable to the induſtry of ages to come; for even chymical tortures have hitherto forced no confeſſions from this *Proteus*, but what raiſe almoſt as many difficulties as they ſolve.

SECT. IV.

BEſides thoſe we have been ſpeaking of, there is another ſort of men, who, boldly relying on the vulgar philoſophy, and their own ſufficiency, pretend to exclude a deity out of the world; tho' many points, magiſterially taught, and confidently believed among them, are erroneous and contradictory to the moſt obvious, as their doctrine is unable to explain the more abſtruſe, phenomena of nature. *The* Epicurean *ſyſtem, which excludes a deity, examined.*

It is obſervable, that by refuſing to aſcribe any thing to God, men impoſe upon themſelves in thinking an inquiry purſu'd far enough when they come to the general cauſe of an appearance, which, tho' more obvious, is no better underſtood than the other. Thus, if you aſk a reaſon why of all bodies gold alone ſhould ſink in quick-ſilver? they anſwer, Gold being of all bodies the only one, that is ſpecifically heavier than quick-ſilver, tho' they are, yet this cannot, by the laws of hydroſtatics, be ſupported therein. But were a curious inquirer, not content with this plauſible anſwer, farther to demand the nature and cauſe of gravity, it wou'd, I fear, be hard to ſatisfy him †.

And,

* This has been ſo very fully and ſatisfactorily done of late, particularly by means of that noble lecture, founded by Mr. *Boyle* himſelf, to defend the chriſtian religion; that the ſect of atheiſts, if ever there was a real one, is entirely vanquiſhed and put to ſilence. Dr. *Bentley* firſt happily began to apply the *Newtonian* ſyſtem to this purpoſe, in his admirable ſermons; and to the ſame inſtitution 'tis we owe Dr. Clarke's *Demonſtration of the being and attributes of God*, Mr. *Derham*'s *Phyſico-theology*, &c.

† This indeed is a hard queſtion, and Sir *Iſaac Newton* himſelf is cautious how he anſwers it. At the cloſe of his *Principia* he tells us, he was not hitherto aſſigned the cauſe of gravity, which is a power, however, that proceeds from a cauſe reaching even the centres of the ſun and planets, without loſing its virtue, and that acts not according to the particles of the ſurface, like a mechanical cauſe, but according to the quantity of ſolid matter in bodies; it's action being every way extended to immenſe diſtances, and always decreaſing in a duplicate proportion of them. The gravity of bodies towards the ſun, he farther ſays, is compos'd of their

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And, doubtleſs, tho' the immediate cauſes of many effects in nature are eaſily aſſignable; yet upon farther inquiring into the cauſes of thoſe cauſes, 'till we arrive at the primary ones, we, perhaps, ſhall find them to depend on ſuch primary affections of the ſmall particles of matter, or ſuch a joint conſpiracy of the ſeveral parts of the univerſe, as it would be impoſſible to account for, without recourſe to an intelligent agent. For the followers of *Ariſtotle* delude both themſelves and others, in pretending to aſſign reaſons for abundance of effects. And not to inſtance in ſuch abſtruſities as they refer to ſympathy, antipathy, and occult cauſes; let us take ſome obvious phenomena, as that of ſuction, or the *Menſes*; the former they aſcribe to nature's abhorrence of a vacuum, and the latter to her providence, leſt after puberty the body ſhou'd be overloaded, and fit nutriment be wanting to the fœtus, in geſtation: ſolutions no way ſatisfactory to a philoſophical inquirer; for both of them ſuppoſe, either the world to be endowed with a kind of ſoul, or that there are intelligent principles in inanimate bodies. Beſides theſe, there are numberleſs other queſtions, relating to the parts of human bodies, the cauſes and cures of diſeaſes, *&c.* which they often anſwer by ſaying, "Nature does ſo and ſo, becauſe 'tis fit ſhe ſhou'd;" without ever explaining what they mean by nature, or how inanimate bodies can act for certain ends: they ought, therefore, 'till their own hypotheſis is more intelligible, either to ceaſe aſcribing to irrational creatures ſuch actions as manifeſtly proceed from reaſon and choice; or elſe to allow, with us, that ſuch creatures perform them by the direction of a wiſe author of things.

And tho' I muſt own that ſome actions, which, perhaps, are peculiar to man, ſeem inexplicable by mechanical principles; yet, with regard to other effects of nature, we may ſuppoſe, that when God determined to make this world, he divided the matter he had provided into numberleſs particles of various figures; which duly ranged, connected, and thrown into proper motions, regularly exhibit, by the continuance hereof, all the diſtant phenomena of the univerſe, as well as if each creature employ'd, acted with knowledge and deſign, or an intelligent Being diffuſed thro' the whole, preſided over, and directed all the parts, according to the laws originally eſtabliſhed. Thus a curious compound engine regularly performs its office, whilſt all the component parts thereof, as if animated by a common principle, conſpire to accompliſh the maker's end.

'Tis in a ſenſe agreeable hereto, that I always uſe the common phraſes in philoſophy: as for inſtance, when I ſay any heavy body tends to the earth's centre, I don't mean that mathematical point has the power to attract it, but that

gravity towards all its particles, and in going from the ſun decreaſes exactly in a duplicate proportion of the diſtance to the orbit of *Saturn*, and even the fartheſt aphelia the comets, if thoſe aphelia are at reſt; but the reaſon of theſe properties of gravity I cou'd never hitherto, ſays Sir *Iſaac*, deduce from phenomena, and am unwilling to frame hypotheſes about them; for whatever is not deduced from phenomena, ought to be call'd an hypotheſis, and no ſort of hypotheſes are allowable in experimental philoſophy, wherein propoſitions are deduced from phenomena, and made general by induction. Thus the impenetrability, the mobility, the moment of bodies, the laws of motion and gravity were diſcovered. And it is enough that gravity has a real exiſtence, and acts according to ſuch laws as we have deliver'd, and that it ſuffices to produce all the motions of the celeſtial bodies, and of our ſea. See *Newton. Princip. Ed.* 2. *p.* 483, 484.

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either the magnentical effluvia of the earth, the preſſure of ſome ſubtile matter*, or whatever elſe be the cauſe of gravity, ſo far determines the heavy body downwards, that if all obſtacles be removed, it will directly fall to the earth's ſurface. In the ſame manner the hand of a clock might be ſaid to affect a circular motion, tho' the metal 'tis made of be indifferent to all motion, becauſe the ſtructure of the machine ſo determines it; and tho' this motion be ſtop'd, yet the hand may ſtill be ſaid to have a tendency to the ſame motion, becauſe, upon removing the obſtacle, 'twill proceed therein. Yet do I not reject ſuch current expreſſions as theſe; "nature affects

* Mr. *Boyle* here, and in ſeveral other parts of his works, ſeems to have entertain'd an opinion as to the cauſe of gravity, and of many abſtruſe phenomena of nature, like what Sir *Iſaac Newton* hints in the concluſion of his *Principia*, and more fully inſiſts upon in the queries annexed to his optics, of a very ſubtile matter that pervades all groſs bodies, and lies conceal'd in them, by the force and actions whereof the particles of bodies attract one another at very ſmall diſtances, and cohere when they come to be contiguous; whereby electrical bodies act at greater diſtances, as well by repelling as attracting ſuch ſubſtances as are near them; whereby light is emitted, reflected, refracted, inflected, and gives heat to bodies; and, laſtly, whereby ſenſation is excited and the voluntary actions of animals perform'd. But tho' ſeveral experiments and obſervations of Mr. *Boyle* ſeem to infer, or require ſuch an agent; yet, I find not that he imagin'd it ſo univerſal, and to have all the properties which are by Sir *Iſaac Newton* aſcribed to it. From what particular experiments its ſeveral neceſſary properties are deducible, is, perhaps, not eaſy for any one leſs verſed in the phenomena of nature and art than that great philoſopher to ſay: but whoever enquires into the cauſe of the firm cohefion of the hard component particles of bodies, which are only laid together, and touch but in a few points, will, as Sir *Iſaac Newton* obſerves, find a neceſſity of ſomething to attract or preſs them towards one another. The ſame thing he alſo infers from the cohefion of two poliſhed marbles *in vacuo*, from the ſtanding of quickſilver in the barometer, at the height of 50, 60, or 70 inches, whenever it is well purged of air, and poured in, ſo that its parts are every way contiguous to one another, and to the glaſs; for the atmoſphere, by its weight, preſſes the quickſilver into the glaſs to the height of 29 or 30 inches, and ſome other agent raiſes it higher, by making its parts ſtick to the glaſs, and to one another; for by any diſcontinuation of parts made by bubbles, or by ſhaking the glaſs, the whole mercury falls down to the height of 29 or 30 inches. The aſcent of liquors between glaſs or marble plates, and in ſmall glaſs tubes, either empty, or filled with ſifted aſhes, which happens as well *in vacuo*, as in open air, are alſo, inſtances to this purpoſe. But farther, ſays Sir *Iſaac Newton*, if in two large tall cylindrical veſſels inverted, two little thermometers be ſuſpended, ſo as not to touch the veſſels, and theſe veſſels be removed from a cold place into a warm one, the thermometer *in vacuo* will grow warm as much, and almoſt as ſoon as the other thermometer which is not *in vacuo*; and when the veſſels are carried back into the cold place, the thermometer *in vacuo* will grow cold almoſt as ſoon as the other: is not therefore, continues that great author, the heat of the warm room convey'd thro' the vacuum by the vibrations of a much ſubtiler medium than air, which, after the air was withdrawn remain'd in the vacuum? And of this medium or æther he thus queries with regard to gravity: Is it not much rarer within the denſe bodies of the ſun, ſtars, planets and comets, than in the empty celeſtial ſpaces between them? And in paſſing from them to great diſtances doth it not grow denſer and denſer perpetually, and thereby cauſe the gravity of theſe bodies to one another, and of their parts toward the bodies; every body endeavouring to go from the denſer parts of the medium towards the rarer? For if this medium be rarer within the ſun's body than at his ſurface, and rarer there than at an hundredth part of an inch from his body, and rarer there than at the fiftieth part of an inch from his body, and rarer there than at the orb of *Saturn*; I ſee no reaſon why the encreaſe of denſity ſhou'd ſtop any where. And tho' this increaſe of denſity may, at great diſtances, be exceeding ſlow, yet if the elaſtic force of this medium be exceeding great, it may ſuffice to impel bodies from the denſer parts of the medium towards the rarer with all that power which we call gravity. And that the elaſtic force of this medium is exceeding great, may be gather'd from the ſwiftneſs of its vibrations, &c. See *Newton. Optic. Engliſh Edition. A.* 1718. p. 323, 325, 326, 364, 372, & *alibi paſſim*.

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the beſt, "nature does nothing in vain, &c." for, as according to my own notion, the actions of irrational creatures are directed by a moſt wiſe agent; I am not ſurprized that their actions reſemble ours, or even ſometimes exceed them. And, in fact, ſilk-worms and ſpiders perform, untaught, what we cannot; birds build their neſts more dextrouſly than a man could; and many other animals perform ſuch things, that 'tis no wonder ſome have aſcribed reaſon to them; tho' this ſeems raſhly done, conſidering much may be ſaid for the immortality of rational ſouls; that the actions of brutes are chiefly limited to the preſervation of their ſpecies; and that they betray a want of thought in every thing beſides. And, therefore, as when I ſee a curious clock, and find every part nicely adapted to its reſpective end, and all harmoniouſly join'd to anſwer the views of the artificer, 'tis the contrivance of the workman, not of his materials, that I admire; ſo when I contemplate the ſeveral creatures of this vaſt engine, the world, I can never ſuppoſe that the inanimate parts thereof act with reaſon and deſign, but adore the wiſdom of the architect, who could produce ſuch regular effects from the joint concurrence of ſo many different cauſes.

It may here be objected, that tho' the ſchool philoſophy fails, yet the *Epicurean* accounts for the production of the world, without having recourſe to a deity; but a conſideration of the doctrine of *Epicurus*, and his paraphraſt *Lucretius*, tho' ſubtile philoſophers, has confirm'd me in the contrary opinion.

Epicurus himſelf, in his epiſtle to *Herodotus*, found in *Diogenes Laertius*, gives this ſhort ſyſtem of his doctrine; "As to meteors, it ought not to be "imagin'd that motion, rotation, eclipſes, riſing and ſetting of the hea-"venly bodies, or any thing of this ſort happens from the direction "of a ſuperintendent, who enjoys happineſs and immortality: we are, "therefore, to believe that at the creation of the world there happen'd ſuch "a convolution of twining atoms as render'd theſe revolutions neceſſary. "There is an infinite number of worlds, only ſome whereof are alike to "this; for as atoms, from the infinity of ſpace, muſt be infinite; they "will meet in various places, and ſo variouſly conſtitute infinite worlds far "remote from this:" which obſcure account of the world's origin *Lucretius* finely illuſtrates, and afterwards applies it to ſome particulars thereof. But his hypotheſis requires many poſtulata too abſurd or uncertain to be granted; for inſtance, "That matter is eternal; that it was actually di-"vided into atoms from eternity, (whereas it might as well be one coherent "maſs; for actual diviſion is in no wiſe eſſential thereto;) that the num-"ber of theſe atoms is truly infinite; that they have an infinite vacuum "to move in; that their figures are almoſt infinitely various, (tho' he ſhews "not how this came to be conical, or that ſpherical;) and that theſe atoms "were ſelf-mov'd from eternity," tho' motion be no more an eſſential property of matter than reſt; being perfectly indifferent to either *. Nor has it hitherto

* Motion and reſt are in the modern philoſophy ſuppoſed to be ſtates of bodies; yet ſome have endeavoured to prove the former eſſential to matter. And, indeed, if a thing may be ſaid to be eſſential where it is a conſtant attendant; perhaps the diſpute is at an end. For all the bodies we are acquainted with, ſeem to be in a perpetual motion. No one will ſay that the parts of animals, vegetables, or minerals are at abſolute reſt among themſelves, who conſiders the

hitherto been ſhewn, how matter can move itſelf. Almoſt all the bodies here below are moved by ſomething external to them; even in animals 'tis not the will that produces ſpontaneous motion: this only determines and directs the nervous fluids of the muſcles, as appears by the fatigue and loſs of ſtrength conſequent upon violent exerciſe. And therefore *Anaxagoras*, tho' he believ'd, as *Ariſtotle* did after him, the eterninty of matter, allow'd a mind was neceſſary to be put into motion. But in the *Epicurean* ſcheme, not barely motion, but alſo its determination is ſuppoſed; for the atoms muſt move downwards, and that too not in parallel, but converging lines; ſo that beſides motion, here is gravity in atoms without a centre for them to tend to, and a particular direction and continuance of motion therein, without any cauſe being aſſign'd for either; which are aſſumptions ſo bold and precarious, that ſome of the author's admirers are aſhamed of them. This doctrine farther ſuppoſes, "that allowing a downward motion to a "ſufficient number of atoms; a fortuitous concourſe in their fall, will, alone, "produce the world, with all its creatures;" that is to ſay, chance may reduce a chaos to order, or a multitude of letters, caſually thrown together, give us the hiſtory of the creation as it ſtands in the book of *Geneſis*.

'Tis true indeed, odd images, reſembling pictures, ſeem accidentally produced in ſtones and other inanimate bodies; but theſe phenomena are fairly to be ſolved from other principles: tho' were theſe allow'd to be real productions of chance, how different are they from what we behold in the ſtructure of animals? To inſtance, in a human body, which tho' compoſed of numberleſs parts, none are ſuperfluous, or can be otherwiſe made or placed without manifeſt detriment; nay, ſome of them, as the eye, valves in the veins, *&c.* are ſo dextrouſly adapted to their reſpective uſes, and entirely unfit for any other, that a more than ordinary underſtanding is required to diſcover the depth of their contrivance. On the other hand, that account which *Lucretius* gives of the firſt formation of man, from poetical wombs, adhering to the ground, which *Lactantius*, at large, expoſes, is ſo unſuitable to ſome other parts of his work, that I am tempted to ſuſpect he wrote it in one of thoſe phrenzy-fits his *Lucillia*'s philtre occaſion'd him.

Let it be farther obſerved, that with all their aſſurance, the utmoſt theſe naturaliſts can do, only ſhews the phenomena of nature may poſſibly be produced after their manner; but as the ſame effects often proceed from different cauſes, it may, ſometimes, be impoſſible to diſcover by what particular means nature obtains her ends. And even *Epicurus*, himſelf, never pretended to aſſign the preciſe cauſe of the phenomena he endeavoured to explain. So that allowing we did, in general, know the phenomena of nature proceeded from the bulk, figure, motion, *&c.* of atoms, we may ſtill be to ſeek for the particular cauſes of any ſingle effect: thus a man might

the growth, increaſe, decreaſe, corruptions and changes of them. Mr. *Boyle* has made it highly probable that the parts of the moſt ſolid bodies, ſuch as glaſs, gems, *&c.* are in motion. And it is now generally confeſs'd that the earth, which itſelf is in perpetual motion, as well as the other planets, and the comets, moves round the ſun; ſo that in ſhort nothing appears to be at reſt in our ſyſtem but the centre of it; and this, poſſibly, is conſtantly going forwards in a ſtrait line. See *Newton. Princip. Ed.* 2. p. 17, 18. 373, 374.

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ſay, in general, the fam'd clock at *Strasburgh*, mov'd by means of wheels, ſprings and weights; tho' he knew nothing of their reſpective magnitudes, figures, motions and proportions, or the particular contrivances of the whole.

But the more eminent *Epicureans* argue thus, "if the phenomena of nature "be not ſolved by our hypotheſis, they are inexplicable;" but this argument is not ſo concluſive as they ſeem to imagine. And tho' it be as bold to aſſert, as hard to prove, that no other philoſophy can do more than theirs; yet, if we allow their concluſion, where's the abſurdity? Who has demonſtrated that men are able to find out and explain all the operations of nature? The moſt learned of our adverſaries own themſelves unequal to the taſk.

It adds no ſtrength to their argument, that their way of ſolving appearances is eaſy and intelligible; for the queſtion is, how things really are produced, not what manner of production is moſt level to our reaſon. And if the world, as they ſay, were caſually made, ſure, chance never conſidered of the moſt intelligible way: but if God be its author, and framed it according to his immenſe wiſdom, how ſhall human underſtanding comprehend the contrivance? And hence we may infer that current argument, "I can-"not conceive it," to be of no force in philoſophy. 'Tis true, we ſhould be cautious of admitting unintelligible things for truths; but there is ſo great a difference in the thinking faculty of men, to ſay nothing of partiality, indolence, want of application, and wilful dulneſs, that what is unintelligible to one, ought never, for that reaſon, to be rejected by another. Thus ſome *Epicureans*, who would reſolve all things by mechanical principles, tells us they can form no notion of an incorporeal ſubſtance, or ſpirit; nor ſuppoſing the ſoul were ſuch, how it cou'd act upon the body; yet others ſolemnly profeſs they have a clear and diſtinct idea of ſpirit, which they believe the human ſoul to be; and deny they can comprehend how any thing ſhou'd think that is material.

Thus much for thoſe who preſume to account for all things without ſuppoſing a God: others, more modeſt, who yet incline to this opinion, might propoſe the following objection. "Tho' we cannot aſſign a real cauſe of every "effect in nature, we take away the neceſſity of a deity, by ſhewing, in ge-"neral, that the phenomena of the univerſe are mechanically producible."

To this I anſwer; firſt, it does not appear that all the phenomena of nature can be ſolved by mechanical principles, as particularly the faculties and actions of men; and if a ſpiritual ſubſtance be here allow'd, not only a fundamental doctrine of the *Epicureans*, "That there is nothing in the "univerſe beſides body and vacuum," is given up, and the poſſibility of a ſpiritual ſuperintendent wou'd likewiſe follow. Secondly, allowing them explicable hereby, 'tis no conſequence that there was originally no need of an intelligent Being to range and diſpoſe a chaos, or infinite number of atoms into a regular world; and to eſtabliſh thoſe principles whereon the production of numberleſs creatures depends: for matter, however figured and moved, ſeems of itſelf as incapable of doing this, as a quill, when cut into a pen, is unable, of itſelf, to write. Beſides, were an *Epicurean* to be told, that a man, after having been many years dead, came to life again, he would, I preſume, reject the relation as of a thing impoſſible. And why, but

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becauſe ſo ſtrange an effect cannot be aſcribed to chance? For he knows no power great enough to collect the ſcattered atoms, whereof, according to *him*, that body was wholly compoſed, and ſo diſpoſe and move them, as again to conſtitute the ſame. This example, indeed, extends not to all the circumſtances of the caſe; but I infer from it, that a conſidering man may happen confidently to reject what is not abſolutely impoſſible; and that ſuch things may poſſibly be effected by matter and motion, as no wiſe man will think produced without the direction of an intelligent agent. Laſtly, *Lucretius* affirms, "That the atoms made no agreement to ſet-"tle into a world," and the very notion of atoms implies them inanimate; ſo that did we grant all the productions in nature to reſult therefrom, the difficulty wou'd ſtill recur, what thus ordered and directed them? It muſt, ſurely, be as abſurd to think that innumerable ſenſeleſs atoms, as that a few more bulky parts of matter, ſhould jumble themſelves into ſo curious a fabric as that of the univerſe, or a human body; and conſequently, 'tis incredible they cou'd, without the guidance and direction of a governing principle, conſtitute either.

SECT. V.

That a philoſopher is by ſome things perſuaded of the exiſtency of God, more than a vulgar mind.

BUT to reſume our former ſubject. Be it true or falſe that ſome things in nature tempt a philoſophical more than a vulgar mind, to doubt the exiſtence of a deity; without diſpute, there are others that perſuade the former of its certainty, more than they do the latter. For many properties of bodies are known to theſe, many ſecret relations, and harmonious correſpondences between the parts of the univerſe, which eſcape a ſuperficial view. So that if, as 'tis ſuppoſed, *Ariſtotle* wrote his diſcourſe concerning the world, towards the end of his life; 'tis remarkable how he, who uſed to be ſceptical enough, riſes, by contemplating the univerſe, to lofty encomiums of its divine architect. But more particularly, he who is ignorant of anatomy, can never receive thoſe demonſtrations of wiſdom, from the circulation of the blood, the motions of the chyle, and other contrivances in a human body, which croud upon an expert anatomiſt. There are fine mechanical contrivances in the hand, the fœtus in the womb, in the muſcle, called *Marſupialis*, that ſerves to move the thigh, and in many other parts of the body. 'Tis not, therefore, ſurprizing that *Galen*, tho' no great religioniſt, ſhould, from contemplating the human ſtructure, take occaſion to compoſe hymns to the creator. And methinks, 'tis impoſſible any man ſhould behold a ſkilful diſſection of an eye, without acknowledging that a good anatomiſt has ſtronger reaſons to admire the author of nature, than one who is unacquainted with that art. Sure I am, it is nothing but our ignorance can hinder us from giving juſt praiſe to God for that excellent manſion wherein the ſoul reſides; ſince not only *David* celebrates him, becauſe, ſays he, "I "am fearfully and wonderfully made;" but anatomical diſſections, as we juſt now obſerved, raiſed even *Galen*'s devotions. Yet perhaps, even anatomy itſelf has not diſcovered to us all the wond'rous contrivances in the human body; nor ever will, till a competent knowledge of the ſeveral animal fluids, of chymiſtry, mechanics and philoſophy, be added to a dextrous manner

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manner of diſſection. Without ſome acquaintance with proportions, 'twill be hard to judge of the ſymmetry of the parts; as without ſkill in optics, 'twould be impoſſible to ſee the wiſdom diſplay'd in the ſtructure of the human eye, compared with thoſe of other animals.

Farther, 'tis manifeſt, from univerſal experience, that the ſtudy of nature leads to the belief, rather than the denial of a ſupreme Being. The ancient philoſophers, who had no revelation, generally acknowledg'd one; as appears from numerous teſtimonies: and if ever any real atheiſt appear'd, their number has been inconſiderable, and their patrons always eſteem'd as monſters. As for the nations that, at this day, are ſaid to worſhip God; they conſiſt not of naturaliſts, but irrational barbarians, who cannot be ſaid to deny, but to be ignorant of him; and that too, becauſe they know ſo little of his works. But if there be any ſuch people as theſe, 'tis a ſtrong recommendation of philoſophy; and ſhews that without the aſſiſtance of ſuppoſed innate ideas, reaſon, alone, exerciſed upon the objects around us, will diſcover a deity. And indeed, as the ſtars in their courſes were ſaid to fight againſt *Siſera*; ſo not only they, but the reſt of the creatures, in their courſes fight againſt atheiſts.

Philoſophy inſtructs us to admire and celebrate God.

Again, philoſophy not content to prove the exiſtence of a God, inſtructs us alſo to admire and celebrate his perfections. The nobleſt worſhip has been paid him by the greateſt part of the world, where his will was never particularly reveal'd, the temple of the univerſe ſufficed to tranſport them with rational wonder at the attributes of its author. And this kind of devotion, commonly riſing, in proportion to the diſcoveries made in nature, the beſt philoſophers among the heathens always ſhew'd the moſt of it. No wonder then, that the *Indian* gymnoſophiſts, the *Perſian Magi*, the *Egyptian* ſacrificers, and the ancient *Druids* were prieſts as well as philoſophers. And were it not too tedious to give inſtances wherein the creatures have manifeſted to philoſophers the attributes of God ſtamped on them, I might have quoted many paſſages out of both ancient and modern writers, to this purpoſe. Moreover, were our adverſaries poſition as true as we have ſhewn it falſe; why muſt a philoſopher, tho' ever ſo knowing, needs be an atheiſt? Philoſophy is only one way of coming to the knowledge of a God: religion has other arguments to enforce ſuch a belief. The devils muſt be well vers'd in philoſophy to inſtruct magicians and their other dependents, and wou'd gladly, no doubt, bend all their knowledge to propagate atheiſm; yet St. *James* tells us, "that they themſelves believe there is a God, and "tremble at him." It follows, that either philoſophy does not, neceſſarily, lead to atheiſm, or that other than philoſophical arguments may convince the moſt obſtinate of the being of a God. But to leave ſpeculation, and come to fact: the ſeaſonable accompliſhment of propheeies and the working of miracles, at once, demonſtrate the being, providence and other attributes of God. And as theſe are the ſtrongeſt arguments divines can uſe for the truth of the chriſtian religion, I hope, they will allow the force of them. I ſay, then, if theſe arguments prove the truth of the chriſtian religion (and what can do it more effectually?) they conſequently prove the exiſtence of God*.

The fulfilling of propheeies, and working of miracles demonſtrate the being of a God.

* With this view it was, that Mr. *Whiſton*, in conformity to the founder's deſign, attempted to ſhew the accompliſhment of the ſcripture propheeies, when choſe to preach Mr. *Boyle*'s lecture. He endeavours to make it appear, that none of thoſe propheeies have a double meaning, and that they reſpectively have, at their due time, been fulfilled.

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Laſtly, ſo far is philoſophy from leading to atheiſm, that it furniſhes us with arguments againſt it. The atheiſts have long preſumed themſelves the only philoſophers, and to perplex others with philoſophical notions; yet a ſkilful naturaliſt will greatly reduce the number of their greateſt difficulties, and eaſily ſurmount them. Eternity, ſelf-exiſtence, and other attributes are objected by the *Epicureans* againſt the being of a God; whilſt they ſuppoſe the origin of local motion, the infinity of ſpace, and the diviſibility of matter, which are full as hard to conceive upon their ſcheme; ſo that inſtead of one God, they confeſs, as we have ſeen, an infinite number of eternal, ſelf-ſufficient, immortal, ſelf-moving atoms; and raiſe many more difficulties to one accuſtomed to leave ſecond cauſes, and contemplate ſuch as have none. *Philoſophy furniſhes arguments againſt atheiſm.*

Upon the whole; I am afraid leſt the delightfulneſs of philoſophy ſhould too much devote men to the creatures, rather than make them diſbelieve a creator; for the beautiful variety of objects here prove ſo charming, that we ſometimes grow negligent of other pleaſures, and even of our religious duties. Tho' God being infinitely better than every thing elſe, he alone can afford mankind their utmoſt ſatisfaction, which thoſe deprive themſelves of, who reſt wholly in the creatures.

But my zeal for philoſophy has hurried me too far, and given my diſcourſe a reliſh of the preacher; yet I have *Seneca* and *Pliny* to bear me out herein: nor, perhaps, is it a fault thus to have treated a ſubject I ſhould not have engaged in, had I found any thing ſatisfactory wrote upon it by others. But as divines are commonly too ignorant of nature's works to treat philoſophically of them; ſo naturaliſts rarely preſume to handle them with a view to religion *. I cannot, therefore, but acknowledge, that, if this diſcourſe any way anſwers the ends I propoſed by it, I ſhall ever eſteem it the beſt part of my works; for I am perſuaded, that whoever could bring philoſophical devotion into the reputation it deſerves, would honour God as much as by erecting buildings for religious uſes.

Nor is this kind of veneration, this λογικη λατρεία, ſuppreſſed by chriſtianity; for God by affording us a revelation, cannot have given up his right to us as rational creatures, in which capacity we offer in the world euchariſts to its creator. *Galen* could ſay, that "to manifeſt the perfections of God to others, "is a greater act of religion, than to burn whole hecatombs upon his altars;" which *Hermes Triſmegiſtus* thus confirms, "The thanks and praiſes of men, "are the nobleſt incenſe that can be offered up to God." And God himſelf is pleaſed to tell us, "that he who ſacrificeth praiſe, honoureth him;" and again, we learn that an acceptable part of religion is the "ſacrifice of praiſe, "and the calves of our lips;" by offering up of which, we make a true uſe of the creatures in referring them to the creator's glory; ſo that as "all things "are of him, and through him, they may alſo be to him."

* This might be a merited reproach when Mr. *Boyle* wrote theſe eſſays; but it has ſince been wiped off, by many excellent writers among the *divines*. 'Twere needleſs to name on this occaſion Dr. *Bentley*, Dr. *Clarke*, Mr. *Whiſton*, Mr. *Derham*, and others, who have preached the lecture of our excellent author.

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PART II.

Shewing the uſefulneſs of natural philoſophy to the art of medicine.

SECT. I.

Philoſophy ſhou'd be reduced to practice.

HAving ſeen the advantages accruing from natural philoſophy to the mind of man; let us next conſider thoſe it brings to his body and goods. And here, I muſt own, that this kind of uſefulneſs is what ſo highly recommends philoſophy to me: 'tis the increaſe of power, not amuſing ſpeculations that I expect from it. Nor dare I aſſume the title of a naturaliſt, 'till the productions of my garden, orchard, or fields, exceed thoſe of others unacquainted in this ſtudy. Wou'd we convince the world of the real uſefulneſs of natural philoſophy, we ſhould take a like method with *Thales*; who, 'tis ſaid, being reproached for ſtudying the ſtars, as a thing of no ſignificance, made all the forehand contracts he cou'd for olives of the enſuing growth; whereby he became immenſely rich: for the year, as he had early foreſeen, proved very bad for oil, which he, therefore, ſold at his own price; and thereby ſhewed that philoſophers rather deſpiſe than covet wealth.

Methinks it is a diſgrace to a philoſopher when he comes to conſider the art of huſbandry, not to be able, with all his knowledge, to improve the precepts which only illiterate perſons have given about it. From the ſchool philoſophy, indeed, nothing of this kind is to be expected; but from the true principles of ſcience, throughly known, and applied, 'tis inconceivable how univerſal and advantageous a change might be made in the world. What a turn has been given to affairs by thoſe two ſlight diſcoveries, the needle's pointing to the north, and the reluctance between ſalt-petre and brimſtone? And what are all the trades in the world, but ſo many corollaries or applications of a few theorems of natural philoſophy?

But the more diſtinctly to ſhew what improvements may be expected in the ſeveral arts by a due application of natural philoſophy thereto; we will divide them into thoſe that relieve our neceſſities, thoſe that accommodate, and thoſe that delight us. To begin with phyſic; tho' I pretend not to be a doctor in that faculty, I ſhall follow the common diviſion of its branches; and briefly obſerve how each of them is indebted to natural philoſophy, or farther improveable by it.

The uſefulneſs of natural philoſophy to the phyſiological part of medicine.

Did I not greatly reſpect *Hippocrates*, I might ſay, that ſome of the bloody laws of *Draco* were leſs deſtructive than his ſingle aphoriſm, "If a pregnant "woman be let blood, ſhe will miſcarry." For experience, at length, has aſ-

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ſured us of the ſafety of phlebotomy, even, contrary to his expreſs aſſertion, when the fœtus is large. But if an error of omiſſion may prove ſo fatal in phyſic, what are we to expect from thoſe of commiſſion, and raſh proceedings? As the phyſician muſt neceſſarily take his principles from the naturaliſt; 'tis ſurprizing that men, eſteem'd wiſe by themſelves and others, ſhould contemn the ſtudy of nature; becauſe we frequently ſee thoſe in poſſeſſion of the greateſt worldly happineſs, at once deprived of it all, thro' the ignorance or miſtake of the doctor.

The advantages of comparative anatomy to phyſic.

Our own age hath ſhewn us what light comparative may give to human anatomy. 'Twere a ſavage cruelty to diſſect, as did *Herophilus* and *Eriſiſtratus*, human bodies alive; nor could many things, as the motion of the blood and chyle, be diſcover'd in a dead one; it muſt, therefore, be of uſe to phyſicians, to ſee living irrational animals diſſected: and thus the lacteal lymphatic veſſels came firſt to be diſcover'd. Many experiments, alſo, may here be made, which it were imprudent to venture upon in the bodies of men. The ſpleen has been cut out of a dog without any damage; and I lately aſſiſted in the experiment ſucceſsfully made upon a young ſetter, that recover'd in a fortnight after the operation. The empiric *Fioravanti*, indeed, ſays he perform'd it upon a ſplenetic lady, who lived many years afterwards; but tho' his relation were credited, the ſituation of the part forbids ſuch an adventurous proceedure. To know, that, tho' frogs have lungs, and uſe them as other terreſtrial animals, they may, without ſuffocation, be detain'd for many hours, nay, ſome days under water, might help to determine the nature of reſpiration. And, generally, the parts of brutes are ſo like the *correſponding* parts in men, that a good acquaintance with the former, will, in moſt caſes, render the trouble of obtaining the latter, unneceſſary. *Galen*, who is allowed to have been no bad anatomiſt, rarely diſſected any other; for in his time 'twas thought irreligious to put human bodies to ſuch uſes. And no wonder, ſince to this day, the uſe of anatomy and ſkeletons is forbid in *Muſcovy*; the firſt, as inhuman; the latter, as ſerving to witchcraft: and we are told by *Olearius*, that one *Quirin*, a *German* chirurgeon there, being found with a ſkeleton, was expell'd the kingdom, and hardly eſcaped with life: and the ſkeleton after being dragg'd about the ſtreets, was burnt.

There are many other advantages of comparative anatomy, which may ſerve to confirm any new diſcoveries, or illuſtrate the true uſe of the parts in men; for ſcarce any creature can be well underſtood of itſelf, much leſs the body of man, without comparing it with thoſe of different animals, to ſee where any part is omitted, wherein it differs in magnitude, figure, ſituation, connexion, *&c.* Thus, on the coaſt of *Ireland*, I obſerv'd a kind of fiſh, about the ſize of mackrel, whoſe hearts ſeem'd to be inverted; their baſis lying towards the tail, with the mucro pointing to the head, and adhering to the *Aorta*. The lungs of vipers, and other creatures, their hearts and blood, which are always actually cold, may make us farther enquire, whether the chief uſe of reſpiration be cool to the heart.

The ſudden and continued collapſion of a dog's lungs, diſcoverable upon a large wound in his cheſt, may afford ſome diſcovery in the principal organ of reſpiration. The hearts of vipers, and ſome ſmaller fiſhes, where the contraction

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and relaxation of the fibres may be diſtinctly obſerv'd, might help to decide the controverſy about the cauſe and manner of the heart's motion. To ſatisfy myſelf in this matter, I have ſometimes cut the heart of a flounder tranſverſly, into two parts; and freeing each from the blood it contain'd, I obſerv'd, for a conſiderable time, that both of them, together continued their former contraction and relaxation. And once, thus cutting one into ſeveral pieces, I found, to my ſurprize, that they not only mov'd as before, but that even the whole thus ſeparated, long preſerv'd the ſame ſucceſſion of motion, as appear'd therein whilſt coherent.

Queſtions concerning the uſe of the heart, and the principal ſeat of life and ſenſe, may alſo receive light from this kind of experiments. I remember, that having cut out the heart of a live frog, without cloſing the wound, he, notwithſtanding, leap'd about the room, as if no hurt had been done him; tho' his entrails hung out, and he dragg'd them after him. Upon his reſting, we prick'd him, after which he leap'd as before; and being put into water, he could ſwim, whilſt his heart remain'd in my hand. We took out the hearts of others more carefully, and ſew'd up the wound, whereupon they leap'd more frequently and vigorouſly than the former; they alſo ſwam, and remain'd in water, as if all their parts were entire; ſometimes they would nimbly leap, firſt out of the veſſel, and then about the room; in ſhort, ſome ſurvived the exſection of their hearts an hour, and others longer. Theſe creatures, notwithſtanding, cannot ſurvive the loſs of their brain. To proceed to warm animals. I obſerved the heart of a chick unhatch'd, but perfectly form'd, to beat for above an hour after the head and breaſt-bone were clipp'd off to diſcloſe it; but the auricles retain'd their motion longer; tho' that of the other parts diſappear'd in a few moments after the head was off. The heart, when dead to appearance, was often, by puncture, excited to freſh motion of ſhort continuance. This experiment we repeated with the ſame effect; but when the motion of the heart, and its auricles became languid, 'twas again excited by placing them in the ſteam of hot water; by which contrivance we kept the heart beating for an hour and an half. At another time, we, by the like method, continued the motion of that of a larger chick for two hours and an half. But this is nothing to the ſtrange vivacity we have obſerv'd in that cold animal the viper; for not only their heart, tho' ſever'd from their bodies, will beat for ſeveral hours; but the body itſelf will continue to twine and twiſt for ſome days after the ſkin, heart, head and entrails are taken from it; and upon puucture, eſpecially near the ſpinal marrow, will manifeſt a vivid motion, after they have long lain quiet. And tho' *Indian* tortoiſes are very large animals; *Vincent le Blanc* tells us, "when the king of *Pegu*, an admirer of them, deſign'd any for "his table, their heads were cut off five days before they were dreſs'd; to the "end of which time they, notwithſtanding, continue alive." To theſe might be added the common obſervations off flies, butter-flies, and other inſects, ſurviving the loſs of their heads; and not only ſo, but as I lately found in butter-flies, that they are capable of procreation afterwards. I ſhall not pretend to draw any certain concluſions from hence; but 'tis ſufficient to my purpoſe, that ſuch kind of experiments have relation to the doctrine of the unceaſing influence of the brain, ſuppos'd requiſite to ſenſe and motion.

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That the colour of the blood is owing to that of the liver, ſeems not improbable from the livers in men; but in hens eggs, after the third or fourth day of incubation, the *punctum ſaliens*, or heart, is found full of very red blood before the naked eye can diſcern a liver, at leaſt any redneſs therein. And in large fiſh I have found the veſſels of the liver full of red blood, tho' its ſubſtance were white.

That the loſs of a limb is irreparable has been unanimouſly believ'd, yet the common caſe of lizards, lobſters, crawfiſh *, and, perhaps, ſome other animals, does not confirm it abſolutely true. The tails of lizards have, after being ſtruck off, been found to grow again. Credible perſons have inform'd me of their obſerving the ſame in lobſters claws; and I, myſelf, have known it in thoſe of craw-fiſh.

An acid in the ſtomach has, of late, been ſuppoſed the cauſe of digeſtion; but in the ſtomachs of ſeveral ravenous ſea-fiſh, my taſte could diſcover no ſuch thing; tho' we found, in one of them, two other fiſhes that meaſured each a foot, in length, whereof that which ſeem'd lateſt devour'd, had ſuffer'd very little alteration, whilſt all the external parts, except the head, of the other, were uniformly waſted, or corroded, far below the original ſurface of its body. Indeed, by a menſtruum drawn from vitriol, as alſo by oil of vitriol, I have diſſolv'd roaſted fleſh into a kind of red or purple gelly, or liquor; and this without the aſſiſtance of heat. Thus then it appears, that the naturaliſt may greatly aſſiſt the phyſician in his anatomical inquiries.

How to preſerve the parts of animal bodies for anatomical purpoſes.

But beſides theſe particulars, the naturaliſt may alſo inſtruct the phyſician how to preſerve the ſeveral parts of human bodies, or other animals. For as the ſtructure, connexion, &c. of the leſs common parts in anatomy, like the alteration of plants in botany, are apt to ſlip out of the memory; it may be refreſh'd by judicious preparations in the one, no leſs than by a proper collection of ſpecimens in the other. We find, by experience, that butter-flies, and other inſects, long retain'd their ſhape and colours, by being left properly tranſfixed with pins on the inſide of boxes. Reflecting once, how long ſpiders, flies, and other animals, have been preſerved by an accidental incloſure in amber; I was induced to try the like expedient with clear *Venice* turpentine: by evaporating which to about two thirds, I obtain'd a reddiſh tranſparent gum, clear of bubbles, eaſily ſoluble by heat, and as eaſily render'd brittle by cold.

* *M. Reaumur* has publiſh'd ſome curious remarks which he made upon theſe animals. He tells us, that ſeveral parts of them will grow again as well as their claws; that their large claws or legs accidentally break near the fourth articulation, reckoning from the tip, and then gradually grow out again to the former dimenſions; that if one of theſe large legs be purpoſely broke at the fourth or fifth articulation, 'twill come again, but either not at all, or not ſo well, when broke at the firſt, ſecond, or third articulation, if it were to be left thus; but that in few days time the creature itſelf, probably, breaks the claw higher about the fourth joint, for it is then found broken thus; after which the re-production goes forwards. He farther aſſures us, that if a part re-produced be broke off a ſecond time, it will, nevertheleſs, grow again. But the ſummer, which is the only time wherein craw-fiſh feed, favours theſe new productions much more than any other ſeaſon. *Memoir. de l'Acad. A.* 1712. p. 295, 321.

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When I deſign it for uſe, I melt it, being firſt pulverized, with a gentle heat, and dip the body to be preſerv'd ſeveral times therein, 'till it gains a caſe of due thickneſs. This ſubſtance, indeed, is inferior to amber, being more apt to gather duſt; but care may prevent that, and then its cheapneſs will recommend it.

Nor are only ſmaller bodies capable of this treatment. The external parts of more bulky ones, as thoſe of birds, fiſhes, crocodiles, and horſes are found preſerv'd in repoſitories; and many anatomiſts can eaſily keep the internal membranous parts uncorrupted. I have ſeen the veins, arteries, and nerves of a human body thus diſplay'd in their proper ſituation, upon boards; as alſo the parts of generation, which continued for many years to be far more inſtructive than a printed figure of them. And I have known the fleſh of vipers kept good for ſeveral years, by the ſmoak of an aromatic powder. The ſkeleton of a monkey has been ſhewn me, with the muſcles rais'd, and curiouſly preſerv'd upon it. And, perhaps, ſome way may be found to keep the arteries and veins plump after they are emptied of blood. A very fluid matter, which would ſoon harden, might do this; ſuch as the liquid plaiſter of burnt alabaſter; the gelly of iſing-glaſs, or ſugar of lead, frequently diſſolv'd in ſpirit of vinegar. To proceed, I have known a fœtus long preſerv'd in oil of ſpike; and a large one, managed in a different manner, appear'd to me, after many years, as entire, plump, and freſh, as if it were newly dead *. 'Tis poſſible, ſome nobler way than what has hitherto been practis'd may, hereafter, be found out; for I ſuſpect that ſaline, corroſive, or hot bodies are not the only ones which ſtrongly reſiſt putrefaction; and that embalming ſubſtances may be effectually applied without mangling the body. *Joſephus Acoſta* relates, that "men, "and the beaſts they ride on, are ſometimes, on certain mountains of *Ameri-* "*ca*, kill'd by the winds; which, alone, afterwards preſerve them from pu- "trefaction." I am acquainted with an experienced gentleman, fam'd for curing cancer'd breaſts, by the external application of an innocent powder: and muſk, to my knowledge, has greatly contributed to the preſervation of fleſh.

'Twere alſo proper to try how far ſpirit of wine would contribute to preſerve a human body; for tho' it ſtrongly reſiſts putrefaction, it does not fret the fleſh; nor will its colour diſguiſe the objects therein contain'd. And I, myſelf, have, for many months, preſerv'd in it very ſoft parts of a body, without any detriment to their figure or conſiſtence; at another time we, for a long while, kept a large quantity of blood ſurprizingly ſweet and freſh, by mixing it herewith; nay, by means of it, we even prevented a piece of a very ſtale fiſh, from farther putrefaction. I have alſo opened eggs at ſeveral days after the beginning of their incubation; and taking out the chicks,

* The ingenious *Ruyſh* ſeems to have advanc'd the art of injecting and preſerving the parts of animals to the greateſt imaginable degree of perfection. The injection he performs by means of inſtruments finer than the threads of a cobweb, as, in his late epiſtle to the learned *Boerhaave*, he expreſly declares; ſo that he ſays he offers no violence to the veſſels, nor, when he pleaſes, diſtends them beyond their natural dimenſions. By this means, and by ſome particular way of preſerving of them afterwards, he has, as it were, re-animated dead bodies.

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embalm'd each of them in a diſtinct glaſs of ſpirit of wine carefully ſtopp'd. When the chick was large, I have ſometimes mixed with the ſpirit of wine a little ſpirit of ſal-armoniac, made with quick-lime; for tho' this abounds with an urinous ſalt, yet I never obſerv'd it to coagulate ſpirit of wine. And I uſually found it convenient to let the little animals firſt lie, for a while, in common ſpirit of wine, to waſh off the looſer filth; and then having put better upon the ſame bird, I ſuffer'd it to ſoak, for ſome time, therein; that the liquor having, as it were, drawn what tincture it could, the ſubject being mov'd into more pure and highly rectified ſpirit of wine, might not diſcolour it. And by this means, alſo, I preſerv'd the head of a monſtrous calf; wherein, tho' the body of the animal ſeem'd otherwiſe perfect, there was no ſign of a noſe in the uſual place; the two eyes being united into one, in the middle of the brow, and furniſh'd with but one large optic nerve. The ſclerotis containing both was ſingle, but ſeem'd to have a ſeam, by which the eyes were join'd, that went quite round; the pellucid part being diſtinctly ſeparated from the two cornea's; each ſeeming to have its iris and pupil diſtinct. Upon opening the cornea, there appear'd two cryſtalline humours. There were four eye-brows in the head. Juſt above the eyes was a deep cavity, out of the middle whereof grew a kind of double purſe, which ſeem'd a production deſign'd for the noſe. Nor is it hard to improve the balſamic virtue of this ſpirit.

From hence it appears poſſible, that human induſtry may, hereafter, diſcover ſuch ways of preparing animal bodies, as will greatly improve anatomical knowledge. But the body conſiſting of fluid, as well as ſolid parts, gives another opportunity to the naturaliſt of improving medicine; by ſhewing not only the difference between ſolidity and fluidity; but alſo by examining into the nature of ſeveral animal juices, with the alterations both they, and the aliments they are made of, undergo in their ſeveral ſtages. For, ſince the human body appears to be only a curious machine; a naturaliſt well verſed in chymiſtry and machines, may, doubtleſs give ſome new light into its phenomena.

SECT. II.

The advantages of natural philoſophy to pathology.

THAT natural philoſophy may aſſiſt the phyſician to diſcover the nature and cauſes of diſeaſes, appears from hence, that tho' the ſimilitude between a human body and the world, be not ſo great as *Paracelſus* imagin'd; yet the ſame phenomena often happen in both, but more conſpicuouſly in the latter; which muſt, therefore, illuſtrate thoſe of the former.

A knowledge of the properties of bodies, and the phenomena of art and nature, uſeful to a phyſician.

And certainly, if a phyſician know not how heat and cold, fluidity and firmneſs, fermentation, putrefaction, viſcoſity, coagulation, diſſolution, &c. are generated and deſtroy'd in moſt bodies, he will be at a great loſs, when he comes to find out the cauſes of diſeaſes; for many of them entirely depend upon the preſence, abſence, or change of theſe and the like qualities. On the other hand, 'tis a fine advantage to have learnt, by a variety

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variety of experiments, the different ways whereby nature ſometimes produces the ſame effects; for ſeveral ſolutions of the ſame appearances may hence ariſe, which, otherwiſe, might never have been dreamt of. This, ſurely, is no ſmall advantage to a phyſician; ſince he, who is only acquainted with a few of nature's ways of proceedure, is unlikely to know how abundance of diſeaſes are produced; and, conſequently, will ſometimes miſtake the cauſe, and apply remedies accordingly; when the poor patient, perhaps, muſt dearly pay for his phyſician's ignorance. He, who knows nothing of the origin and growth of ſtones out of the body, is unable to explain their production in the bladder and kidneys. Many famous phyſicians, we find, have ſuppoſed them generated from ſlime baked to a hardneſs by the heat of the part; and, accordingly, directed for cure, remedies to moiſten and cool the kidneys. This notion could hardly have obtain'd but from the ignorance of the ways of petrifaction in other caſes; for a liquor may turn wood into ſtone; give to other bodies hardneſs and weight; and even produce cryſtals in cold water: nay, in ſuch cold aquatic animals as craw-fiſh, ſtrong concretions are generated otherwiſe than this hypotheſis ſuppoſes; for thoſe bodies, falſely call'd crabs eyes, are, at certain times of the year, taken out of their heads. And the *offa alba* of *Paracelſus*, produced upon a due mixture of ſpirit of urine and ſpirit of wine, is a different kind of concretion, ſerving to illuſtrate the ſame.

That an earthy ſubſtance may lurk undiſcern'd in a limpid liquor, appears from wine, which throws off to the ſides of the containing veſſel a ſolid tartar; clear common urine, alſo, affords a ſediment, and if diſtill'd before it ferments, leaves an earthy portion, and commonly ſome gravel behind. Nay, rectify'd ſpirit of urine will, upon long ſtanding, let fall a precipitate, and throw a multitude of ſmall concretions to the ſides of the containing glaſs, like thoſe that are found in urinals. By barely mixing two diſtill'd and tranſparent liquors together, I have often immediately obtain'd a blackiſh, dry, and brittle coagulation: and by this means *Helmont* attempts to account for the generation of the ſtone in human bodies. And tho' none of theſe ways be, of themſelves, ſatisfactory, 'tis ſomething to give a probable account of this diſtemper, which ſeems more difficult and abſtruſe than ſeveral others. So that not only philoſophy, but chymiſtry alſo, may contribute to clear up the nature of ſome diſeaſes.

The *Galenic* phyſicians uſually account for catarrhs, by comparing the ſtomach to a boiling pot, and the head to an alembic, wherein the vapours being condenſed by the coldneſs of the brain, diſtil upon the lungs, or other adjacent parts; which hypotheſis, however inſufficient, manifeſts, that chymical operations may illuſtrate the doctrine of diſeaſes. And ſince the fluids of the body abound in ſaline and ſulphureous parts; he who underſtands the nature of ſalts and ſulphurs, their actions upon each other, as well as different bodies, ſeems better qualify'd to diſcourſe rationally about their changes and operations, than one who is ignorant herein. To know that acid juices may lodge in the ſtomach, and elſewhere; that the ſerum is coagulated by heat; that the blood abounds in volatile and ſulphureous, but manifeſts no acid ſalts; that animal ſalts and ſpirits, as ſpirit of urine, or that of hart's-horn,

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horn, are able to make a red ſolution with the flowers of ſulphur; that ſpirit of urine, or of human blood, will ſoon make a blue one with crude copper; to know the conſiſtence, ſmell, crackling, and other qualities of the lympha, when expoſed to the fire; how acid liquors loſe their acidity by working upon ſome bodies, as vinegar upon coral; and how ſaline ones degenerate into ſalts of another nature by working upon others, as oil of vitriol upon quick-ſilver; how acid and ſulphureous ſalts, ſometimes diſarm, ſometimes, after ebullition, precipitate each other, and ſometimes unite into a third ſubſtance, of a nature different from either, as the vitriolated tartar; in a word, to have made numerous careful trials upon the human body, as well as other productions of nature, and to have applied the obſervations made on the latter, to illuſtrate thoſe of the former, more enables a man to explain ſeveral particulars in pathology, than an ignorance of theſe things.

The chymiſts, methinks, ſpeak too ſlightingly of the humours of the body, and allow them too little ſhare in the production of diſeaſes; for the relations of *Skenkius*, and other eminent phyſicians, as to the corroſiveneſs of ſome animal juices, rejected by urine or vomit; which, they ſay, would ferment on braſs, fret linen, and tarniſh ſilver; incline me to believe, that too much has formerly been aſcribed to the humours, as hot and dry, cold and moiſt, and too little to the ſaline and ſulphureous properties of them. And *Hippocrates* ſeems to confirm this opinion. "'Tis not, ſays he, cold or heat, moiſture or dryneſs, that "produce ſo great effects as bitter and ſalt, ſweet and acid; inſipid and ſharp; "when they come to be unduly mixed, and when any of them predominate." And were theſe juices chymically examined by one who knows how to volatilize fix'd bodies, and to fix volatile ones; 'tis probable, many things relating to the nature of the humours, and the ways of ſweetening, ſharpening, and otherwiſe altering them, with the importance of ſuch an alteration, may be diſcovered. Nor might it be unſerviceable to extend this examination to the noxious juices of diſtempered bodies; as the phlegm expectorated from unſound lungs, the ſlimy excretions in a lientery, or the fluid that diſtends the abdomen in a dropſy; which latter I found of a different nature from either water or urine; for it would keep long without putrefying; and upon evaporation over a gentle fire, when freſh, it firſt grew ropy, then ſizy, and at laſt glutinous.

Stones found in the human bladder, chymically examined.

Thus, in order to examine the ſtone of the human bladder, I carefully opened two that had been cut out by a lithotomiſt, and found each of them to conſiſt of ſeveral coats, that ſucceſſively involved each other, like thoſe of an onion: and the ſame I ſince obſerved in a large ſtone taken out of an ox's gall. They were nearly as hard as common ſtones, tho' they differed from each other therein. In one of them we found an intermediate coat, differing in colour from the two contiguous ones. Some of the coats were the length of a barley-corn in thickneſs; and tho' they cloſely adhered to each other, they were actually as well as viſibly ſeparable. In the centre of one of them, we found a ſmall ſoft oval ſtone, ſo looſe that we picked it out, and preſerved it as a rarity. After this, they were finely powdered, and put into a ſmall glaſs retort, ſtrongly coated; and luting a receiver thereto, two ounces and a half, the whole weight of the ſtones, being diſtilled for ſome hours in a naked fire, afforded a large quantity of volatile ſalt, and a reddiſh ſpirit, which in the receiver coagulated into ſalt. Upon ſeparating the veſſels, we found, in the neck of the receiver, a little dark-coloured oil,

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oil, but much more in the neck of the retort, incorporated with a good deal of volatile ſalt, of a ſcent and a taſte not unlike thoſe of the ſalt of unfermented urine. The *Caput mortuum*, a light coal-black powder, appeared like fine ſoot, and weighed about ſix drams; which ſhewed that above two thirds of the ſtones, being volatile, had, in a cloſe veſſel, been forced by diſtillation from the terreſtrial parts thereof; while the *Caput mortuum* remained fixed enough to give a ſuſpicion that it contained a heavy oil: calcining it, therefore, we reduced it to about two drams of an inſipid white calx; which did not fall aſunder, like lime, when caſt into water.

Subſtances of a mineral nature found in human bodies.

From this example it ſhould ſeem no great error in the followers of *Paracelſus*, to ſay that arſenical, vitriolic, aluminous, and other mineral-like ſubſtances, are generated in human bodies. We find ſtony concretions not only in the bodies of men, but of ſucking children. The heat, it is true, is not violent here; but why ſhould that alone be ſuppoſed the efficient of all the changes our aliment undergoes, when there are diſſolvents, ferments, ſtrainers, and other powerful agents ſucceſſively working upon it? A very eminent perſon told me, that in the fits of an odd diſtemper, ſhe ſometimes vomited up ſo ſharp and fretting a matter, that it burnt her throat, in its paſſage, like ſcalding water; ſtained the ſilver veſſels it was received in, and even worked upon them like a corroſive menſtruum. And an intelligent gentleman, alſo, lately complained to me, that in the fits of a ſtrange diſtemper he laboured under, he frequently obſerved that part of his pillow along which his breath paſſed, was thereby blacked over, as if it had been held in the ſmoke of a fire.

We might here obſerve, that the ſame water which in paſſing thro' a vine or an apricot tree, becomes ſweet fruit, in the lemmon or barberry-tree is converted into a liquor able to corrode pearl and coral, like ſpirit of vitriol. Nay, credible writers affirm, that a certain *Indian* fruit will immediately corrode and waſte the ſteel inſtrument 'tis cut with, if its juice remain upon it; as we ſee ſome of our apples and pears will ſoon black the blades of knives. I have cauſed a *Ranunculus* to increaſe conſiderably in weight and bulk, by allowing its root nothing but fair water. And as this plant is reckoned poiſonous, and when externally applied, capable of raiſing bliſters; why may not ſuch aliment as contains many parts more active than water, receive from ſeveral concurring cauſes ſuch an alteration in a human body, as to render it like foſſil ſalts, or other minerals? Do we not ſee cancers, ulcers, and ſharp humours generated in the body, deſtructively imitate the operations of arſenic and corroſive ſalts? The infuſion of antimony hardly more ſtimulates nature to diſburthen her ſelf by the mouth and *Anus*, than doth ſometimes a fretting humour; as that which cauſes the *Cholera morbus*, or other more violent diſtempers.

And that aliments ſhould thus degenerate in diſtempered bodies, is leſs ſtrange than that water ſhould be changed into an hot veſicatory ſubſtance; tho' to leſſen the wonder, I can ſay, that from a ſingle pound of common bread, I have obtained many ounces of a menſtruum, which will operate upon bodies more compact than ſolid minerals, or glaſs it ſelf; and that too more ſtrongly than could be expected from *Aqua fortis*. Theſe things are mentioned to intimate how chymical experiments might be uſefully applied to illuſtrate pathology, either by imitating, artificially, ſuch kinds of morbific matter as are ſometimes found

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found in the body; or by reſolving that which is therein generated, to diſcover its nature. Not that I think chymical experiments alone ſufficient to explain the doctrine of digeſtion, or diſeaſes; it would be difficult from hence to ſhew how nutrition is performed; or how the feeding only on vegetables ſhould plentifully ſtock the blood and urine with a volatile ſulphureous ſalt; for plants don't yield it by diſtillation. Much harder would it be from chymical principles to account for the hereditary propagation of diſeaſes; or to ſhew how madneſs, and ſome other diſtempers, which appear not viſibly to affect the organs, whoſe functions they pervert, ſhould not only prove hereditary, but lurk for many years in the body, before they manifeſt themſelves; and ſometimes deſcend from grand-father to grand-child, ſkipping the intermediate ſon. I ſay, therefore, that vulgar chymiſtry cannot ſolve all the pathological phenomena, tho' the true kind may aſſiſt in many caſes; and ſome ſeem inexplicable without it. Let me add, that a thorough knowledge of the nature of ferments and fermentations would, probably, conduce to the ſolution of many phenomena of diſeaſes, which, perhaps, will never be underſtood by any other means. There may, 'tis true, be effervescencies, and, perhaps, periodically, in the blood and other juices, without a proper fermentation. For as, at the decline of coughs, the phlegm no longer ſtrongly adheres to the veſſels of the lungs; ſo other humours, either by growing more fluid, or the blood becoming fitter to diſſolve them, may circulate herewith, and thereby occaſion preternatural heats; whether thro' an indiſpoſition to incorporate with it, by altering its texture, diſturbing its motion, preventing its due rarifaction, obſtructing the finer canals, cauſing extravaſations, or any other means*. Experiment has ſhewn there are liquors wherewith if *milk, oil, or even* water be mixed, a remarkable heat will immediately enſue. And I have made uſe of a menſtruum, wherein fleſh will, in a few minutes, excite an heat ſcarce tolerable to him who holds the containing glaſs in his hands. Nor is this the effect of a true fermentation, but rather of the diſturbed motion of the particles of the menſtruum; wherein the nature of heat ſeems chiefly to conſiſt.

Anatomy tends to advance pathology.

But a naturaliſt may not only thus illuſtrate pathology as a chymiſt, but alſo as an anatomiſt. The diſſection of ſound brutes may promote the diſcovery of the correſponding parts in human bodies; and the anatomy of morbid beaſts often gives light as to the ſeats and cauſes of diſeaſes in men. 'Tis certain, pathology has been greatly improved by the diligence of the moderns in diſſecting of morbid human bodies, and thereby diſcovering the ſeat and effects of the peccant matter that proved deſtructive. And the knowledge gained hereby may be augmented or illuſtrated by making the like obſervations on brutes. Thus, by a chymical analyſis of the blood of ſheep, deer, *&c.* its phlegm, ſpirit, ſalt, and oil are found very like thoſe obtained in human blood; and in the bodies of ſeveral other animals, worms, impoſthumes, and the like, ſeem manifeſtly to ariſe from the ſame cauſes, they do in us. And 'tis very remarkable that conſiderable quantities of graſs have been found in the *Aſpera arteria* of cattle, when they were opened; and chyle in the veins of men. 'Twas thro'

* *Bellini* deduces the cauſes and ſymptoms of fevers from a lentor of the blood, tho' what that lentor is, he no where, that I remember, fully declares. This paſſage may, therefore, ſerve as an explanation of that term; and *Bellini*'s whole doctrine of fevers, may well be conſider'd as a comment upon this uſeful hint.

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want of ſuch knowledge that *Helmont* aſſerted the ſtone to be a diſeaſe peculiar to man. There are alſo diſeaſes, for the cauſe whereof, the compreſſion o' ſtruction or irritation of ſome nerve, the diſtenſion of ſome vein, or an obſtructed circulation of the blood in ſome part, are aſſigned; in which caſes we may ſafely venture to make an experiment in brutes thus affected, in order to ſhew the truth or falſhood of the ſuppoſition, and eſtabliſh a juſt method of cure.

An hemiplegia, occaſion'd by a ſmall ſplinter of a bone preſſing upon the dura mater.

A very tall and well-ſet gentleman, aged about 24 years, had his ſkull broken in ſeveral places, by a fall from his horſe; and being a perſon of a good eſtate, ſeveral chirurgeons attended him in the courſe of his ſickneſs; during which, he was ſeveral times trepann'd, and had ſeveral pieces of his ſkull taken off, which left great chaſms, as I have ſeen, between the remaining parts. Within about three days after his fall, this gentleman was ſeized with a dead palſey on his right ſide, tho' it did not equally affect his arm and leg; the uſe of the latter being ſometimes ſuddenly reſtor'd to him in ſome meaſure, and after a while almoſt as ſuddenly loſt: but his arm and head were conſtantly paralytical, being wholly deprived of motion; his arm having ſo little ſenſe, that it would ſometimes lie under his body without his feeling it. But if his hand were prick'd with a pin, he could take notice of it. This palſey continued during almoſt the whole time of the cure, which laſted 24 weeks. And when the chirurgeons were going to cloſe up his head, as having no more to do; one of them, who was an ingenious man, oppoſed all the reſt, alledging, that, if they did no more, the gentleman would lead an uſeleſs and very melancholy life; and that he was confident, the palſey was ſome way or other occaſion'd by the fall, which had left ſomething in the head that they had not yet diſcover'd. And the gentleman himſelf agreeing to the motion, his head was further laid open; and at length, under a piece of proud fleſh, they found, with much ado, a ſplinter of a bone, that bore hard upon the *dura mater*, and was not pull'd away without a great hemorrhage, and ſuch a ſtretch of the parts, as made the patient think his brain it ſelf was tearing out. But this was ſoon remedied, and his wound ſecurely heal'd up; and he is now a ſtrong healthy man, and finds no inconvenience by having ſo broad and various a *Callus* inſtead of the ſkull; except that he is a little liable to take cold in his head. But the memorable circumſtances, for the ſake of which I mention this hiſtory, were theſe. 1. The bone laſt taken out was leſs than half the nail of one's finger, and almoſt as thin; being in ſize and ſhape like the ſcale of a fiſh; tho' it did not in his head lie flat, but bore hard upon the *dura mater*. 2. He, in leſs than five hours after this bone was taken out, found himſelf able to move his little finger; and (tho' this happen'd in the evening) he was the next morning able to move all his fingers, and within two or three days after, to lift up his arm: by which it ſeemed manifeſt, that ſo little a body as the ſplinter, produc'd, in ſo robuſt a perſon, a palſey of the whole ſide it lay on. For he found no relief till the bone was pull'd out, that is, till long after the chirurgeons had been by degrees eating off the proud fleſh that grew about it. 3. Remembring the important controverſy among modern phyſicians and anatomiſts, about nutrition by the nerves, I inquired whether he did not find a waſting in the limbs of his body that were affected? He told me, that when he began to be paralytic, the ſide affected, greatly waſted by degrees, and that the paralytic leg was very much

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much extenuated; but the arm and hand much more; seeming nothing but a system of bones, with the skin pasted on them; that upon the removal of the *bony* splinter, the consumption of the part also began to lessen; and that in *no* very long time, his leg and arm recover'd their proper dimensions. And *I* lately saw the restor'd arm well plump'd up with musculous flesh, tho' the weather were exceeding cold. He further told me, that he found no difference between the limbs that had been paralytic, and the others; except that they would grow sooner, and more sensibly cold in sharp or frosty weather.

This gentleman assured me, that during the course of his cure, he was almost every second day let blood; that he wanted not an appetite; that for the most part, he slept indifferently; and lastly, that upon so great a hurt, he did not vomit, nor had afterwards any convulsions.

To proceed, there is a whole class of diseases produced by poisons, towards obtaining a knowledge whereof, experiments upon brutes might greatly conduce; for altho' some things may be poisonous to man, that are not so to other animals, *& vice versa*; yet, as the greatest number of poisons affect both equally, the exhibition of them to brutes will afford good opportunities for observing their effects. * Thus a dog, I remember, bore a quantity of opium sufficient to kill several men; and a cat run mad upon having a large dose of it given her.

I am convinced by experiments, that vipers are poisonous only by their bite, when enraged *; and that the immediate application and continuance of a hot iron to the wound they then make, will prevent the ill consequence thereof.

Experiments to be made upon brutes, to acquaint us with poisons and their antidotes.

This I my self tried in a man, who, for a reward, provoked a black viper, and suffered *himself* to be bitten by it; upon which the injured part instantly swelled: but having applied a heated knife as near the wound as he could endure it, for 10 or 12 minutes, the swelling did not increase, and the man received no farther harm. † I could wish more experiments were made about poisons, to determine whether their operations appear'd more sudden by being receiv'd at the mouth; by being applied externally; or by wounding particular vessels with instruments dipt therein. For, I remember to have seen some *Indian* poisons, whose noxious efficacy was affirm'd to appear at different distances of time, and to prove differently mortal, according as the arrow infected therewith open'd a capillary or a larger vein; or wounded a part that lay near or remote from the heart. This, indeed, I have not tried, so don't depend upon. *Olearius* also, in his travels, tells us of a venomous insect in *Persia*, by the natives called *Encureck*, which he supposes a kind of tarantula, that neither stings nor bites; but letting fall his venom like a drop

* The poison consists in an actual liquor, contain'd in peculiar bags, which in about the quantity of a drop, is forcibly immitted in the bite. This venomous liquor view'd thro' a microscope appears to be a parcel of small rigid salts briskly floating in a fluid, which when extravasated, soon shoots into crystals, incredibly small and sharp; with something like little knots up and down therein. *See* Mead *of Poisons*, P. 9, 45, 147.

† But this remedy failed *M. Caras*, and is not so certain as the viper-fat, rubb'd into the wound soon after it is received. Dr. *Mead* successfully made the experiment with it twice, upon dogs; and 'tis the principal thing whereon the viper-catchers rely, when they are bitten. *See* Mead's *Essays on Poisons*. Ed. 2. p. 27, 30. For more experiments made with vipers, *See Philos. Transact.* No. 87. p. 50, 60.

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of water, it immediately cauſes inſufferable pain in the part, and ſoon afterwards ſo profound a ſleep, as only one remedy can raiſe from, and that is to cruſh one of thoſe creatures upon the part affected. Theſe inſects, nevertheleſs, are eat by the ſheep of that country without any hurt. I know alſo, by ſad experience, what an external application of *Cantharides* can do. Having once occaſion for a large veſicatory in my neck, *Cantharides* were put into it as an ingredient, without my knowledge; which waked me in a few hours after the application, with an exceſſive torment about the neck of my bladder; but I ſoon relieved my ſelf by drinking new milk, well ſweeten'd with ſugar-candy *.

I may here mention ſome late experiments made to ſhow the effects of liquid poiſons conveyed immediately into the blood; and particularly that famous one of Mr. *Chriſtopher Wren*, who contrived a new way of injecting them. I procured a large dog, into the vein of whoſe hinder leg we convey'd, by a ſyringe, a ſmall doſe of a warm ſolution of opium in ſack. The effects whereof became manifeſt as ſoon as we cou'd looſe the dog from the cords wherewith his feet were tied; for he immediately began to nod and reel as he walk'd; whereupon, to preſerve his life, I ordered him to be kept awake by whipping, which after ſome time brought him to himſelf; ſo that he ſoon grew fat upon it †. The ſame gentleman, at another time, injected in the ſame manner about two ounces of *Vinum benedictum*, which operated ſo violently that it ſoon killed the dog.

I afterwards wiſh'd, that not only deleterious drugs, but their antidotes, ſtrong liquid cordials, and alteratives, might likewiſe be injected, in a large doſe: and was told it had been ſucceſsfully tried with diuretics ‡. I alſo propoſed that the ſame experiments might be made upon malefactors; and not long afterwards a foreign ambaſſador, reſiding in *London*, inform'd me that he cauſed ſome *Vinum benedictum* to be thus injected into an inferior ſervant of his, who had deſerved the gallows; but the fellow fainting, or pretending to faint, as they were about it, occaſion'd them to deſiſt. It might likewiſe be of

* The common remedy in this caſe, and which may not improperly be call'd the ſpecific for it, is a ſtrong ſolution of gum-arabic in water, ſweeten'd and drank pretty freely.

† Dr. *Mead* forced into the ſtomach of a ſmall dog, about half a dram of crude opium diſſolved in boiling water. This the dog quickly vomited up, but afterwards the Doctor made him take, and retain 3 or 4 ſuch doſes in about an hour's time; when the dog began to ſleep, but preſently ſtarted up with convulſions, fell into univerſal tremblings, loſt the uſe of his hind-legs, which preſently grew ſtiff; then, on a ſudden his limbs grew limber, and he died. Being opened, the ſtomach was found wonderfully diſtended, and ſomewhat inflamed. The pylorus was contracted, the blood-veſſels of the brain very full, with a lump of concreted blood in one part of it. *Eſſays on Poiſons*, p. 152, 153.

‡ Dr. *Friend* made the following experiments, with a view to ſhew the manifeſt alterations that different medicines would cauſe in the blood.

1. Having injected into the jugular vein of a dog, ʒiiſs of the panacea of opium, the dog expired in 4 minutes; no ſtiffneſs appearing in his limbs. Upon opening the *Vena cava* and deſcending trunk of the *Aorta*, the blood flow'd out exceedingly thin and bright; the lungs appeared red, and much diſtended. The blood was wonderfully fluid in the heart; and the ventricles thereof were as free from any coagulum, as if they had been waſh'd with hot water.

2. Six

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of ſervice in phyſic to transfuſe the blood of one animal into another; and with this view 'twere proper to obſerve, whether by transfuſing of blood, the diſpoſition of individual animals of the ſame kind, may not be much altered: as

Inquiries for the transfuſion of the blood of animals.

2. Six drams of *London* laudanum, being diſſolved in cinnamon water, and given to another dog; he was preſently after, ſeized with trembling, and convulſions, which were followed by a prodigious ſalivation. In a quarter of an hour the dog died. Being open'd, there was found in his ſtomach and guts, a milky matter intimately mix'd and ting'd with the laudanum. The arteries and veins were remarkably diſtended, and the blood, all over the body, was incredibly rare and thin.

3. Two ounces of ſpirit of wine were injected into the jugular vein of a dog; and his body being opened in half a quarter of an hour after, the blood in all the veins and arteries was found ſtrongly concreted into clots; but more ſo in the ventricles of the heart,

4. Six drams of ſpirit of ſal-armoniac, prepared with quick-lime, being injected into the jugular vein of a dog; he was, within a quarter of an hour, convulſed over his whole body. The crural vein being firſt open'd, and next the jugular; the blood that ran out was very fluid and thin, ſmelt ſtrong of the urinous ſpirit, and appeared full of bubbles of air. Soon after half an ounce more of the ſpirit was injected, the dog expired. His thorax being open'd, the lungs appear'd exceeding red, and as it were inflam'd; and the blood in all the arteries, and veins, and alſo in the heart, was vaſtly thin and rarified; only in the deſcending trunk of the *Vena cava*, from the liver to the heart, 'twas found thick and compact; as when 'tis extravaſated, and a little cooled. This doubtleſs, happened, becauſe that whilſt the ſpirit was continually propell'd from the jugular into the right auricle of the heart, the blood in the deſcending *Vena cava* cou'd not come to the heart; ſo that being there detained and ſtagnant, it requir'd ſuch a conſiſtence.

5. An ounce and half of a ſtrong decoction of the *Peruvian* bark was, likewiſe, injected into the jugular vein of a dog. In a quarter of an hour, he was taken with a ſtrong and frequent pulſation of the heart, and afterwards with convulſive twitchings. Half an ounce more being injected, he died convulſed. From the crural and axillary vein, when opened, there flow'd a bright liquid blood. The thorax being open'd on the day following, the lungs appeared exceeding red and turgid; much blood was found compacted in the right ventricle of the heart, but little in the left, and that ſufficiently fluid. It alſo run fluid and more rare than in its natural ſtate, from the *Vena portæ* and the jugular.

6. At nine o' clock in the morning, two ounces of *Lower*'s chalybeate tincture were given to a dog; and little change appeared in him; only he ſtagger'd as if he were drunk: at 12 o' clock he ſwallow'd an ounce of ſteel, prepared with ſulphur, mix'd up in butter: and at three in the afternoon the doſe was repeated: at 6 two ounces more of *Lower*'s tincture were injected into the jugular vein. Upon which he preſently began to reſpire ſtrongly, and his heart beating violently for an hour after. When dead, his abdomen was opened, the periſtaltic motion of the inteſtines was obſerved to continue for a long time. A maſs of chalybeate matter found in the ſtomach; all the guts, their internal coats appearing tinged of an iron colour: the blood-veſſels and the lacteals were greatly diſtended. From the iliac vein, when cut, there flow'd a liquid blood, as if the dog had been alive: and from the heart, where wounded, it ſprung out with a force, and appeared exceeding rare and red. At 12 o' clock a large quantity of blood appear'd yet fluid in the heart, and the canals belonging to it; but it was leſs fluid than in the former experiment.

7. A dog being made to take a dram of corroſive ſublimate, was, in a quarter of an hour, ſeized with a vomiting and violent convulſions; and in an hour's time it made him purge, and he died. His abdomen being opened, all the viſcera appear'd exceeding red, and in many places inflam'd; a very large quantity of extravaſated blood lying about the pancreas, ſo that the glands thereof appeared diſtinct, as if they had been ſeparated from one another. The canals, alſo, were ſo diſtended that the ſmall veſſels, which run between the coats of the veins and arteries, were viſible. The kidneys and ſpleen were filled with a liquid blood. The lungs appeared red and turgid; and a very large quantity of totally fluid blood was found in the heart; and the ſame ſort iſſued from all the veins and arteries.

8. An ounce and half of the ſpirit of vitriol, being injected into the jugular vein of a dog; he was ſoon taken with a difficulty in his reſpiration; and with the utmoſt labour of his lungs, died convulſed. The blood in his veins was

as whether a fierce dog, by being quite new ſtocked with the blood of a cowardly dog, may not become more tame, and *vice verſa*.

Whether immediately upon unbinding a dog, repleniſhed with adventitious blood, he will know and fawn upon his maſter; and do the like cuſtomary things as before? And whether he will do ſuch things better or worſe, ſome time after the operation.

Whether the peculiarities of dogs, will either be aboliſhed, or impaired by transfuſion? As whether the blood of a maſtiff, being frequently transfuſed into a blood-hound, or a ſpaniel, will not prejudice them in point of ſcent?

Whether acquired habits will be deſtroyed or impaired by this experiment? As whether a dog taught to fetch and carry, to ſet, *&c.* will, after frequent and full recruits of the blood of dogs, unfit for thoſe exerciſes, be as good at them as before?

was found very thick and greatly concreted; but ſo unequally, that much of the ſerum ſeem'd uncoagulated. A thick grumous matter fill'd the ventricles of the heart, almoſt like a polypus; black blood ſtagnated in the lungs, and a part, being extravaſated, adhered to ſome of the lobes thereof. The ſame ſpirit of vitriol, being injected into a dog, which a little before had taken two ounces of liquid laudanum, turned his blood exceeding liquid, part of which was juſt before let out from a vein, grumous.

9. A little dog having by injection received into his jugular vein two ſcruples of *Saccharum Saturni*, diſſolved in half an ounce of the decoction of pomegranate ſhells; the motion of his heart preſently began to languiſh; his reſpiration became hard and difficult; and convulſions ſeizing him, he died in five minutes. The jugular and iliac veins being opened, blood iſſued out thereof, that was partly fluid, and partly grumous and thick concreted, ſomething like an oil floating upon it, which in taſte reſembled *Saccharum Saturni*. The blood in the aorta was ſo concreted, that it was almoſt fibrous. The lungs were full of coagulated blood, and in ſome places inflamed. The blood in the heart was ſo concreted, that it ſeemed to grow to the pillars of its ventricles.

10. Half a dram of dragon's blood, diſſolved in warm water, being, at twice, injected into the jugular vein of a large dog; the motion of his heart, and his reſpiration were more frequent, and afterwards, without any ill ſymptom, he ſuddenly fell down dead. Soon after, the muſcles of his thorax were ſo convulſed, that they appeared both to the ſight and touch alternately to contract and relax themſelves. The jugular vein being opened towards the head, a frothy blood came out, almoſt one half whereof was clotted. That in the iliac vein was wholly concreted into a ſolid maſs; ſome ſmall portions of it appearing as compact as if the cavity of the vein had been injected full of wax. The ſmall veſſels which run thro' the external coat of the kidneys, were very viſible: the lungs appeared turn'd with concreted blood; and the heart was greatly diſtended with ſome, that, in the right ventricle, was as thick as gelly; but more ſolid in the left.

11. Two ounces of vinegar, thrown into the jugular vein of a dog, only cauſed his heart to beat more frequent; two ounces more made his reſpiration difficult and troubleſome; but this went off upon letting out a large quantity of blood, which appeared ſomewhat clotted, from the iliac artery. The ſame doſe being again injected, the dog expired. A very thick maſſy blood came from the iliac vein when opened; in the other veins, and in the arteries, 'twas lightly concreted; but in the heart, and eſpecially in the left ventricle thereof, ſome part of it was ſtrongly coagulated.

12. Half an ounce of *Spir. Salis Dulc.* injected, after the ſame manner, into another dog; his reſpiration thereby became ſtrong and high; but by degrees it ſunk ſo faſt, that the dog died before the injection was finiſhed. The blood appeared greatly concreted in a'l the veins and arteries. The lungs were inflamed, the heart filled, and, as it were diſtended with blood; ſo that four ounces were taken from the right ventricle, concreted like a gelly. In the left there was little, but ſtrongly coagulated; and in the aorta 'twas like a polypus.

13. Half a dram of ſalt of ſteel, diſſolved in two ounces of water, and injected into the jugular vein of a dog, gave him a palpitation of the heart, and a very great difficulty of reſpiration; upon which he died. The blood in the iliac vein was not concreted, but a little clotted. In the heart and aorta it was ſomewhat coagulated, but leſs than in other experiments. *Friend Emmenolog.* p. 167, 171. 180—183. For more experiments of this kind, made upon arterial and venal blood, and upon the ſerum, *See Pitcairn, Element, Med.* p. 28—33.

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Whether any conſiderable change is to be obſerved in the pulſe, the urine, or other excrement of the receiving animal, or in the quantity of his inſenſible tranſpiration?

Whether, the other dog being full fed at ſuch a diſtance of time before the operation, that the maſs of blood may be ſuppoſed to abound with chyle, the receiving dog, being hungry before, will loſe his appetite more, than if the emittent dog's blood had not been ſo chylous? And how long, upon opening a vein of a dog, the admitted blood will be found to retain chyle?

Whether a dog may be kept alive without eating, by frequently injecting the chyle of another, taken freſhly from the receptacle, into the veins?

Whether a dog that is ſick of ſome diſeaſe, chiefly imputed to the maſs of blood, may be cured by exchanging it for that of a ſound dog? And whether a ſound dog may receive ſuch diſeaſes from the blood of a ſick dog, as are not otherwiſe of an infectious nature?

What will be the effect of frequently ſtocking an old and feeble dog with the blood of young ones, as to livelineſs, dulneſs, drowſineſs, *&c.*

Whether a ſmall young dog, by being often freſh ſtocked with the blood of a young dog of a larger kind, will grow bigger than the ordinary ſize of his own kind?

Whether any medicated liquors may be injected, together with the blood, into a dog? And in caſe there may, whether will there be any conſiderable difference found, between the ſeparations made on this occaſion, and thoſe, which would be made, if ſuch medicated liquors had been injected, with ſome other vehicle, or alone, or taken in at the mouth?

Whether a purging medicine given to the other dog, a while before the operation, the receiving dog will be thereby purged, and how?

Whether the operation may be ſucceſsfully practiſed, in caſe the injected blood be that of an animal of another ſpecies, as of a calf into a dog, *&c.* and of a cold animal, as of a fiſh, frog, or tortoiſe, into the veſſels of a hot animal, and *vice verſa?*

Whether the colour of the hair or feathers of the receiving animal, by the frequently repeating this operation, will be changed into that of the other?

Whether by frequently transfuſing into the ſame dog, the blood of ſome animal of another ſpecies, ſomething further and more tending to a degree of change of ſpecies, may be effected, at leaſt in ſimilar animals, as ſpaniels and ſetting dogs, *Iriſh* grey-hounds, and ordinary grey-hounds, *&c?*

Whether the transfuſion may be practiſed upon pregnant bitches, at leaſt at certain times of their gravidation? And what effect will it have upon the whelps*?

* From ſeveral experiments of the transfuſion of the blood, mentioned in the *Philoſophical Tranſactions*, it appears, that the blood of young creatures, admitted into old ones, makes them, as it were young again. And the principal advantage hitherto gained by ſome experiments is the knowledge that one animal may live with the blood of another; and that thoſe animals, which want blood, or have it diſtempered, may be ſupplied with a ſufficient quantity of ſuch as is good from other animals.

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SECT. III.

The advantages of natural philoſophy to the ſemeiotical part of medicine.

THO' the ſemeiotical part of phyſic ſeems leſs capable than any of receiving improvements from natural philoſophy; yet by giving light to anatomy and pathology, 'twill enable a phyſician the better to form a judgment upon the conſtitutions of his patients, and the ſymptoms of their diſeaſes. For certainly, to be acquainted with the ſolids and fluids of the body, is the beſt qualification for this purpoſe. A naturaliſt, alſo, by improving the curative part of medicine, may alter the duration, ſeverity, and event of diſtempers; for the common predictions of phyſicians are built upon the preſent eſtabliſh'd remedies, and a dogmatical method of cure: whereas, if generous and powerful medicines were diſcover'd, they need not ſo often, in acute caſes, wait for a criſis to inſtruct them *; and the threatning ſymptoms of chronical diſtempers would preſently prove fallacious.

The Peruvian *bark recommended for agues.*

When the *Peruvian* bark was ſcarce heard of among us, I recommended it to ſeveral of my friends afflicted with quartans, in the moſt unfavourable ſeaſon of the year; and under ſuch diſadvantageous circumſtances, that their phyſicians only hopes depended upon better conjunctures; yet, to the ſurprize of them all, it never failed. Some, indeed, ſuffered relapſes, but they were again relieved by repeating the medicine; ſo that many eminent phyſicians, moved by theſe examples, gave into the uſe of it, and were never deceived thereby †. And granting relapſes do happen, yet it is very ſerviceable to procure a reſpite, wherein a phyſician may have recourſe to other remedies; tho' the bark is every way ſufficient in a prudent hand that knows how to aſſiſt it by gentle purgatives ‡. I cannot, therefore, but wonder it has never been tried in other diſeaſes; for 'tis highly probable that a medicine able to prevail againſt ſo obſtinate a diſtemper as a quartan, wherein many of the moſt conſiderable parts of the body are affected, ſhould be ineffectual in others §. But whether this remedy expels the morbific matter, or alters

* This is an uſeful hint to phyſicians: to wait for a criſis is leaving the diſtemper to itſelf; to promote it, is determining the fate of the patient the ſooner; but to prevent it, where this can be done with ſafety, is the thing we ought principally to endeavour.

† 'Tis a curious obſervation of Dr. *Freind*, that phyſicians unjuſtly complain of the uncertain effects of remedies; and that the fault they attribute to the medicine, is in truth their own. For he ſhews that the different operation of remedies ariſe not from a change of virtue in the medicament, which continues always the ſame, but from the different ſtate of the body wherein it is applied. The action of the former, ſays he, is ever ſimilar to itſelf; tho', according to the different diſpoſition of the body, it may ſeem to produce different, and, perhaps, contrary effects. Thus the ſame fire will ſoften ſome things and harden others, by acting in the ſame manner; and a fever, if the blood be thin, will raiſe the pulſe, but depreſs it, if that be thick: ſteel, if the veſſels will ſuffer a farther diſtenſion, opens obſtructions, but increaſes them if the veſſels will yield no more: emetics prove cathartic if the ſtomach be ſtrong; and cathartics prove emetic if that be weak: ſudorifics thin the blood, but do not promote ſweat, unleſs the cuticular glands be free and open, *&c.* See *Emmenolog.* p. 148-155.

‡ This method is now generally practiſed with happy ſucceſs; and we are obliged to Mr. *Boyle* for ſetting it on foot.

§ Mr. *Boyle* is often an excellent guide to phyſicians, and recommends nothing to them without reaſon. This advice, alſo, has been happily put in practice; and the bark is ſucceſsfully uſed as a ſtomachic, an aſtringent, a ſtrengthener, a cordial, *&c.* and ſtill ſeems applicable to many other purpoſes.

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its texture, ſo as to render it harmleſs; or whether it afterwards ſecretly produces any noxious effects in the body, muſt be a work of time to diſcover *. In the mean while, if *Riverius* has not flatter'd his *Febrifugum*, there will be no want of a ſafe remedy for quartan agues.

To proceed, as ſtubborn a diſeaſe as is that of the king's-evil, we have known it cur'd, as we ſaid above, by a ſlight and eaſy remedy. I might add, that an experienced chymiſt, has promiſed to ſhew me a way of making very uncommon, yet rational predictions, in ſome abſtruſe diſeaſes, by examining the patient's urine. But as ſome chymiſts have written extravagantly upon a like ſubject; and as I have not hitherto ſeen the experiment, I dare not offer this as an inſtance of what I am endeavouring to ſhew. But 'tis not altogether improbable that by precipitation, and other unuſual ways of examining the urine, made by the ſame patient, at ſeveral times before, during, and after ſome great alteration in the body; many diſcoveries, particularly in acute diſeaſes, may be made, eſpecially, if other excrements of the ſame patient be at the ſame time chymically examin'd.

Too many diſeaſes eſteemed incurable.

That queſtion, concerning the curableneſs of all diſeaſes, might eaſily be determin'd, by obſerving 'tis one thing to aſk, "whether all diſeaſes be curable," and a different one "whether all perſons are recoverable;" for a diſeaſe may be incurable, either in its own nature, or by accident: that is, either 'tis incurable in every patient, or the circumſtances of a patient may render it ſo. No follower of *Paracelſus* wou'd affirm every diſeaſe to be curable in every patient; nor would a moderate *Galeniſt* aſſert that the gout, the dropſy, and the ſtone, are univerſally incurable.

'Tis true, I cannot but condemn the vain-glory of *Paracelſus*, and his followers; yet I think mankind obliged to the chymiſts for giving us hopes of performing greater cures than were before their trials attempted. For, till the world was awaken'd by many promiſes, and ſome great performances of *Arnoldus de Villanova*, *Paracelſus*, *Rulandus*, *Severinus*, and *Helmont*, phyſicians made very free with the word incurable; and wou'd rather detract from nature and art, than confeſs that both, in conjunction, could perform more than ordinary medicines. And, I fear, there are ſtill too many, who, tho' they will not openly ſay, certain diſeaſes are incurable; yet wou'd undervalue, if not deride him, who ſhould attempt to cure patients afflicted with them. So that I am apt to think many men have been ſuffered to die, whoſe lives might have been ſaved, wou'd phyſicians have attempted to ſave them. 'Twere, therefore, doing no ſmall ſervice to mankind to make a collection of the cures of ſuch perſons as have recovered after being pronounced incurable by the doctors, to prevent them, for the future, from fathering their own ignorance upon the weakneſs of nature; and pretending to the world that the art of phyſic muſt fail with their ſkill. Nor ſhou'd the cures of nature be omitted in ſuch a catalogue, becauſe they ſhew what may, poſſibly, be done by natural means, to evacuate the morbific matter, or change its nature; or elſe how far the tone of a part, or ſtrength of the body, may be vitiated or impair'd

* It has hitherto proved a ſafe and admirable medicine, in prudent hands; and is ſtill a noble ſpecific in intermitting fevers, without leaving any dregs, or ill effects behind it, as was long the out-cry againſt it.

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whilſt it remains capable of ſome reſtitution. Dr. *Harvey* told me, that "a "patient of his was perfectly cur'd of a confirm'd cataract, by the uſe of "phyſic that promis'd no ſuch effect." The learned *Petronius* alſo mentions "a venereal patient, who, having formerly loſt the ſight of one eye by "a cataract, recover'd it by the uſe of the mercurial unctions preſcribed him "for his other diſtemper." And Mr. *Hollyer*, the lithotomiſt, gave me an account of "a maid, who had ſo far loſt the ſenſe of feeling in the external "parts of her body, yet without any diminution of her motion; that, tho' "he deſignedly pinn'd her handkerchief to her bare neck, ſhe would walk "about with it ſo fix'd, unſenſible of what had been done. But continu- "ing, (added he,) a long time in the hoſpital, uncur'd; Dr. *Harvey*, out of "curioſity, viſited her; and, ſuſpecting the caſe to be hyſterical, adviſed her "parents to marry her; which being done, ſhe was, according to his predicti- "on, reliev'd from that ſtrange diſtemper."

That, in acute diſeaſes, perſons given over by phyſicians may recover, none will deny. *Celſus*, himſelf, ſays, "it ought to be obſerv'd, in acute caſes, "that the ſigns of life and death are very fallacious;" and *Hippocrates*, that maſter in prognoſtics, allows them to be uncertain; whence the *French* proverb, "'tis better to be ſentenced by the doctor, than the judge." Nay, even in chronical diſeaſes, where events uſually anſwer the phyſician's prognoſtics; there are, ſometimes, ſuch cures perform'd, as may encourage human induſtry, and prevent a ſick man's friends from deſerting him, while any life remains. For it not only frequently happens, that perſons given over by ſome phyſicians, are cured, perhaps more fortunately than ſkilfully, by others; but thoſe whom judicious and experienc'd men have deſpair'd of, thro' the ſuppoſed incurableneſs of their diſeaſe, rather than their perſonal condition, have been recover'd by powerful remedies. And of ſome ſuch cures I am, myſelf, a witneſs. Among other accounts I have receiv'd of the cures of cancers, perform'd by Dr. *Harberfeld*, phyſician to the king of *Bohemia*, I cannot omit that upon an *Engliſh* woman, above ſixty years old, whom, after having long lain in an hoſpital in *Zealand*, with a cancer'd breaſt, he perfectly cured thereof, in the ſpace of ſix weeks, by one ſingle internal remedy. This relation was made me by perſons of great veracity; the one a phyſician, an eye-witneſs of the cure; the other a child of *Cornelius Drebell*, who not only ſaw the cure, but knew the woman before that time, and was the perſon who brought her to the doctor. The ſame perſons inform'd me, that the medicine was a chymical liquor, which being given, about a ſpoonful or two for a doſe, worked ſuddenly, and briſkly, by vomit; ſo that its operation ended within an hour or leſs, after it was taken. Some of it they preſented me with; and finding it to taſte like vitriol, I ſuſpect that to be its chief ingredient. They farther aſſured me, that having obtain'd of the Doctor a large quantity of that ſpecific, they had therewith, both in *England*, and elſewhere, perform'd ſurprizing cures in the king's-evil. And an eminent gentleman of this nation, now alive and healthy, was cured thereby; tho' the king's-evil had brought his arm to that condition, that the chirurgeons appointed the time for his amputation. And, by the internal

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uſe of the ſame liquor, they profeſs themſelves to have cur'd many external and inveterate ulcers. But theſe are rather chirurgical than phyſical cures.

The ſad prognoſtics phyſicians uſually make of dropſies, particularly the *Aſcites*, are too frequently verified, when they only preſcribe common medicines. I remember a happy cure of this diſtemper perform'd by a *German* phyſician, of whom I had heard a great commendation in *Holland*. I found him, in many reſpects, a modeſt man; and tho' he durſt not promiſe to cure ſo formidable a diſeaſe, he acknowledg'd himſelf poſſeſs'd of one remedy which had never hitherto fail'd him; tho' try'd upon perſons of different ages, ſexes, and conſtitutions. And as incurable as the radicated gout is imagin'd, eſpecially in intemperate perſons; yet I knew an honeſt merchant in *Amſterdam*, who, after being ſo long tormented with it, both in his hands and feet, that his fits would confine him a great part of the year, and not leave him without hard knots in his joints, was cured with a very few doſes of a powder and tincture, not only of his pains, but gouty nodes; and tho' he indulg'd himſelf the free uſe of *Rheniſh* wine, he has never had a fit ſince that time, which is ten or twelve years ago, as himſelf aſſured me.

How far a ſkill in chymiſtry*, and other parts of philoſophy, may aſſiſt to diſcover more able remedies than are yet current among us, might be ſhewn in many other inſtances; but I chuſe to inſiſt upon that of the ſtone in the bladder. *The ſtone in the kidneys and bladder diſſolvable.*

* Chymiſtry, as it has of late been cultivated, appears no leſs ſerviceable in philoſophy than phyſic. And 'tis ſurprizing to ſee how Sir *Iſaac Newton* applies it to the nobleſt purpoſes in nature. Dr. *Friend*, in his chymical lectures, has undertaken to give a mechanical account of the principal operations of this art. To which end, he lays it down, by way of poſtulatum, that all ſimilar bodies are in a triplicate ratio of their homologous ſides; and if of the ſame denſity, that their weights are as the cubes, but their ſurfaces, as the ſquares of their diameters; that the moments of bodies are in a ratio, compounded of their quantity of matter and velocity; that if a body be ſpecifically heavier than a fluid wherein it is immerſed, it deſcends with a force anſwerable to its exceſs of gravity; but if lighter than the fluid, it aſcends with the force whereby its gravity is exceeded by that of the fluid; that there is an attractive power in all the parts of matter which diffuſes itſelf but to ſmall diſtances; being ſtrongeſt at the point of contact, and decreaſing in more than a duplicate ratio of the diſtances; that this power differs with the various texture and denſity of the particles, and is greater on one ſide of the ſame particle than on the other; that the ſmaller the particles are, they approach each other with the greater velocity; and, laſtly, that the force, by which particles cohere among themſelves, proceeds from attraction, and is variouſly changed, according to their various degrees of contact. By means of theſe *Lemmata*, which are proved by geometrical writers, and, particularly by Sir *Iſaac Newton* and Dr. *Keil*, he attempts to ſolve the phenomena firſt of calcination, diſtillation, and ſublimation, which he ſuppoſes to be analytical operations; and ſecondly, of fermentation, digeſtion, extraction, precipitation, and cryſtallization, which he treats as ſynthetical. In the firſt place, when the Doctor ſuppoſes that liquefaction happens while the fiery corpuſcles inſinuate themſelves between the particles of bodies, and disjoin them, ſo that they touch each other in fewer points than before; as appears from the rarifaction of the body diſſolved: and from the different coheſion of the parts of bodies he deduces all the variety that happens in liquefaction. Calcination, ſays the Doctor, is the effect of liquefaction continued; wherein the more volatile Corpuſcles fly off, and the particles of the fire enter the body in ſuch plenty, and intimately mix themſelves therewith, that it can no longer appear in the form of a fluid; and hence, ſays he, the weight of the calcin'd body is increaſed. And vitrification, according to him, is no more than a greater degree of calcination; as common glaſs is made by a long continued fuſion, which throws off the lighter

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der. For tho' it be almoſt univerſally pronounc'd incurable, I remember the famous *Monardes*, treating of the ſeed of a *Peruvian* plant, call'd *Chalchoos*, tells us, 'tis highly eſteem'd by the inhabitants of the country, wherein it grows, not only for a diuretic but a lithontriptic, "of which, ſays he, they "produce ſo many inſtances, that I cannot but wonder at it." And the learned Dr. *Gerard Boot* had a famous remedy for the ſtone, wherewith, as he told me, he had frequently cured it in the kidneys; but that in the bladder he thought impoſſible to be diſſolved: yet a little before his death, he acknowledged he had then lately done it to one Mr. *Moulin*; and that too by his conſtant medicine, the diſtill'd water of arſmart, which he accidentally learnt from a country Gentleman, who had cured great numbers therewith.

Being ſome years ſince in *Ireland*, I met with an ancient empiric, famous for cutting for the ſtone in the bladder: who having given ſome good proofs of his ſkill where I happen'd to be, I conſulted him upon a ſuſpicion I long had of a ſtone in my bladder; but he, upon ſearch, aſſur'd me there was none; as I afterwards found it. I then aſked him, if he had any diſſolvent for the ſtone; he anſwer'd, he could cure no man of a confirm'd ſtone, without the help of his knife; but as for lumps of gravel, not firmly cemented, he had an internal remedy, by which, with a particular way of cruſhing them, with his finger, from without, he could render them voidable by urine. And by this means, he ſaid, he had cur'd a citizen of *Cork* of a large ſtone; which, upon inquiry, I found to be true, and therefore purchas'd his receipt.

Cardan relates, that in his time there travell'd a man over *Lombardy*, who, by a certain liquor, ſafely, ſpeedily, and certainly cur'd the ſtone in the bladder: and *Laurembergius* has told the world how he cur'd himſelf of the ſame by *Millepedes*, &c. And, indeed, the beſt arguments that are brought to ſhew

lighter, and more droſſy particles: hence the gravity of the glaſs exceeds that of the materials whereof it is compos'd. Secondly, the Doctor aſcribes the aſcent of fluids, in diſtillation, to their diminiſhed weight, by means of rariſaction; and the impulſe of the fire; which acting with great velocity, may raiſe very heavy particles. Whence the time of elevation, in bodies diſtill'd, is in a compound proportion, of their rariſaction and ſpecific gravity. Thus ſpirits of wine, of ſal-armoniac, &c. being ſpecifically lighter, and more ſuſceptible of rariſaction, aſcend eaſier by the ſame heat, in diſtillation than common water: as acid ſpirits, which are heavier than that, require a longer time to carry them into the receiver. The increaſed ſurface of the rarified particles, will, alſo, greatly contribute to their aſcent in diſtillation, becauſe this expoſes them the more, to the action of the fire. Thirdly, the impelling force of the fire, is, according to the Doctor, the principal cauſe of the elevation of the parts of ſolid bodies in ſublimation. Fourthly, the Doctor defines fermentation to be an inteſtine motion of the parts of bodies, ariſing from ſolids, diſſolving in a liquor, or menſtruum; and this operation he divides into diſſolution and ebullition. Diſſolution happens, ſays he, if the corpuſcles of the body to be diſſolved, attract the particles of the fluid, more ſtrongly than they attract one another; in the mean time, the included air, being rarified, breaks out, and cauſes an ebullition, and the motion increaſing, a heat enſues. Fifthly, the Doctor accounts for digeſtion, in the ſame manner, by the attraction of the particles; only, that in this, there is heat made uſe of. Sixthly, he ſays, that precipitation ariſes, if a liquor of a leſs ſpecific gravity being pour'd into a menſtruum of a greater, leſſens the gravity and tenacity of its parts, ſo as to let the particles, which are now ſpecifically heavier than the fluid, fall down; or when the particles of a liquor ſpecifically heavier than the menſtruum, carry down with them, when pour'd into it, all the ſolid particles floating therein, which now lie at the bottom; being ſpecifically heavier than the menſtruum. In the laſt place, the Doctor tells us, that cryſtallization is immediately and entirely performed by the attraction of the ſaline particles concern'd.

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the ſtone to be incurable, without cutting, ſeem inconcluſive. If appeal be made to numerous fruitleſs attempts, the preceding experiments may be oppos'd: beſides which, *Horatius Augenius* tells us, "he cur'd a youth at *Rome*, "who was going to be cut for this diſtemper; and likewiſe that the *Jeſuit*, "who confeſs'd him, perſuaded him to uſe *Millepedes*; having experienc'd "their efficacy both upon himſelf and others:" and, indeed, I have found them to be highly diuretic and aperitive.

If it be objected, that medicines muſt loſe their virtue before they can reach the bladder, I grant this is commonly true: yet ſome medicines do retain their nature after many alterations and digeſtions; as turpentine, aſparagus, and rhubarb, manifeſtly affect the urine. Again if it be ſaid, tho' a liquor were found capable of diſſolving the ſtone, 'twill be ſo corroſive as to fret the inteſtines or bladder; I anſwer, that vinegar will diſſolve crabs-eyes, which like the ſtones we are ſpeaking of, are form'd in animal bodies; and even the more ſolid body of coral. The bare juice of lemmons and barberries readily diſſolves both pearl and coral. What *Paracelſus* and *Helmont*, indeed, relate of their *Alkabeſt*, wherewith they prepared their ſpecific againſt the ſtone, and pretended to reduce all ſtones, minerals, *&c.* into inſipid water; I require farther evidence for before I believe: yet a chymiſt, who often adviſed with me about preparing this liquor, proſecuted the buſineſs ſo far, as to bring me a liquor I was ſurpriz'd at; for it not only diſſolv'd common ſulphur, and brought it over the helm; but reduc'd antimony into ſweet cryſtals, with a few whereof, to the aſtoniſhment of many, Dr. *C.* without purge or vomit, cur'd Sir *C. C.* of a very radicated and deſperate diſeaſe. To the ſecond part of the objection it may be replied; did we know and conſider well, how many operations of natural bodies depend upon the ſuitableneſs and difference of the figures of their parts, and the pores interſperſed between them; the number of impoſſibilities would not appear ſo great as they now do.

That it is very poſſible for one body to act upon another, without acting, in like manner, upon different bodies, ſeemingly more expos'd to that action, appears from the load-ſtone, which attracts iron, and not wood or ſtraw. And to come nearer our caſe; quick-ſilver, that will not corrode the ſkin, nor affect the tongue with pungency, readily diſſolves the compact body of gold, which even *Aqua fortis*, that corrodes all metals beſides, will not touch; and yet quick-ſilver will not diſſolve iron, whilſt *Aqua fortis* inſtantly frets it aſunder*. So that, tho' I dare not believe all that's affirmed by the chymiſts, as

* As to the manner wherein metals are diſſolved by a menſtruum, hear the great Sir *Iſaac Newton*. "When *Aqua fortis*, ſays he, or ſpirit "of vitriol, pour'd upon filings of iron, diſſolves "the filings with a great heat and ebullition; is "not this heat effected by a violent motion of "the parts, and does not that motion argue, that "the acid parts of the liquor ruſh towards the "parts of the metal with violence, and run forcibly into its pores, 'till they get between its "outmoſt particles, and the main maſs of the "metal, and ſurrounding thoſe particles, looſen "them from the main maſs, and ſet them at "liberty to float off into the fluid? And when "the acid particles, which, alone, would diſtil "with an eaſy heat, will not ſeparate from the "particles of the metal, without a very violent "heat, does not this confirm the attraction between them?——When *Aqua fortis* diſſolves "ſilver, and not gold, and *Aqua regia* diſſolves

as to their having made, or ſeen, inſipid diſſolvents of gold, ſilver, and other compact bodies; becauſe I have hitherto been unable to procure them; yet many things that I have not only read, but heard and ſeen, keep me from poſitively denying their poſſibility. And who knows but that art or nature may afford a liquor whoſe parts ſhall be adapted to the parts of a human calculus, as thoſe of quick-ſilver are to the pores of gold; whilſt its operation upon the body is no greater than that of quick-ſilver upon iron? Steep an egg in ſtrong vinegar, for ſome days, and the external ſhell will be eaten away, whilſt the thin ſkin contiguous to the white of it, remains entire; the operations of diſſolvents muſt, therefore, be determinate by the textures of the bodies whereto they are applied: ſo that a liquor uncapable of corroding a hard and ſolid body, may be unable to penetrate a ſoft and thin one, of a texture unfit to admit the particles of the menſtruum. Another thing that encourages me in this opinion, is, the relation of *Sennertus*, who tells us, that in the year 1632, "his friend Dr. *Neſter* inform'd him, there then lived in his neighbourhood, a man of *Lorain*, call'd *Claudius*, about 58 years old, who frequently devour'd coals, bones, wood, ſtones, glaſs, metals, *&c.* and even the moſt filthy things that could be offered him; of which, ſays the Doctor, among others, I was an eye-witneſs." *Sennertus* adds, "that not hearing of this *Claudius* for ſome time, he ſent to inquire what was become of him, when the Doctor return'd a letter from the miniſter of the place, to confirm the firſt account; himſelf declaring the man, whom he had long hoped to diſſect, was yet alive, and continued to devour all things as formerly; tho' his teeth being now blunted, he did it leſs frequently." More examples of this kind we meet with in writers of good credit: *Columbus*, particularly, records one of a glaſs-eater, mention'd, alſo, by *Sennertus*. And, not long ſince, there was, here in *England*, a private ſoldier very famous for digeſting ſtones; with whom a curious perſon purpoſely convers'd for a day together; during which he obſerv'd him to eat nothing but pretty large ſtones; and found his excrement chiefly conſiſted of a ſandy ſubſtance, as if the ſtones he devour'd had been diſſolv'd in his body. Theſe caſes, ſurely, prove, that a menſtruum not ſo corroſive as to fret the body, may diſſolve ſtones, and other compact ſubſtances. But if a liquor, prepared by nature only, can, in a human ſtomach, diſſolve that great variety of bodies above mention'd; why may not a menſtruum, produced by aſſiſting and heightning nature to the utmoſt, be capable of diſſolving ſubſtances of different textures? It muſt, indeed, be acknowledged, that ſuch common menſtrua as diſſolve one body, will oftentimes not meddle with another; which may proceed rather from our want of ſkill to prepare the moſt powerful menſtruum, than any impoſſibility in the thing; ſo that

"ſolves gold, and not ſilver, may it not be ſaid "that *Aqua fortis* is ſubtile enough to penetrate "gold as well as ſilver, but wants the attractive "force to give it entrance; and that *Aqua regia* "is ſubtile enough to penetrate ſilver, as well as "gold, but wants the attractive force to give it "entrance? For *Aqua regia* is nothing elſe than "*Aqua fortis* mixed with ſome ſpirit of ſalt, or "with ſal-armoniac; and even common ſalt diſſolved in *Aqua fortis*, enables the menſtruum "to diſſolve gold, tho' the ſalt be a groſs body." *Newton. Optic.* p. 352, 358.

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I don't ſee why a menſtruum may not be obtain'd whoſe variety of parts, figures, and motions, might gain it admiſſion into different bodies. Thus, tho' *Aqua regia* diſſolves gold, but not ſilver, and *Aqua fortis* diſſolves ſilver, but not gold; yet quick-ſilver will diſſolve both gold and ſilver, copper, tin, and lead *.

And becauſe this ſuppoſition, that penetrating menſtrua are proportionably corroſive, is apt to ſtop the inquiries of judicious men, I can aſſure them, that from common houſhold-bread, as was formerly hinted, I have, by a gentle heat, obtain'd a ſpirit, which, when rectified, would operate on the hardeſt bodies ſo far, as in a ſhort time and without fire, to extract a ſtrong tincture from coral, blood-ſtone, unpowder'd granats, and, even, the hardeſt of bodies next to diamonds, rubies. And that theſe high tinctures did not proceed from a change of colour in the menſtruum, I convinced my ſelf by obſerving that it would, from ſome minerals, force a deeper colour than from others; and that, when kept ſeparate, it continued clear and limpid for many months.

But it may be farther objected, that "what diſſolves the ſtone in the bladder of one man, may not do the ſame in that of another;" I reply, this has never been proved; and were it true, as the ſpecifics for agues, fluxes, and the like, are juſtly prized, tho' their effects be not equally ſtrong in all patients; 'twill be worth knowing that the ſtone is not, in its own nature, an incurable diſeaſe: and it would well reward any man's induſtry to relieve even a few from its torture.

This diſtemper I the rather choſe to inſiſt upon, becauſe 'tis generally thought abſolutely incurable by internal remedies, in any ſubject whatever: but having dwelt too long upon it, I defer conſidering the dropſy, and ſome others that commonly ſtand in the catalogue of incurable diſeaſes. I ſhall only add, that altho' *Helmont* and *Paracelſus*, by the ſhortneſs of their own lives, ſeem to give teſtimony againſt themſelves; yet they certainly invented ſome extraordinary medicines; ſuch, for inſtance, were their laudanums: yet none of them were comparable to the preparations of *Butler*. This man, as *Helmont* relates, "had a ſmall ſtone, which being ſlightly plung'd into oil, or almond-milk, communicated ſuch a ſanative virtue thereto, that a ſpoonful of the former cur'd a *Franciſcan Friar* of a dangerous eryſipelas in the arm, in the ſpace of an hour; and one drop of the latter applied, in his preſence, to a woman's head, immediately reliev'd her from an intolerable *Hemicrania*; and tho' ſhe had been for ſixteen years afflicted therewith, it return'd not, to his knowledge, in ſeveral years." He adds almoſt as ſtrange a cure perform'd, in one night's time, upon a ſervant of his wife, by anointing the part affected, with four drops of the ſame oil. Nay farther, he tells

Butler's Stone.

* 'Twill, according to the late Mr. *Hawksbee*, by no means account for the ſuſpenſion of heavy ſolid bodies in lighter fluids, that the ſolid gains a large quantity of ſurface, by being divided into minute parts therein; which is the common way of accounting for this phenomenon. For he found, by experiments, that the difference between an ounce of ſolid glaſs, and *the ſame quantity* reduced to fine powder; between a ſquare inch of ſheet-braſs, and 225 ſquare inches, that is, an equal weight of tinſel *laminæ*, weigh'd in water, is vaſtly too ſmall for this purpoſe. He, therefore, concludes, that the ſuſtentation of metals, and other ſubſtances, heavier *in ſpecie* than the fluids, which diſſolve them, are kept floating therein by the principle of attraction. *Hawkſbee's Experiments*; p. 231—236.

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us, " that the maſter of the glaſs-houſe at *Antwerp*, being grown enormouſly " fat, was ſoon reduced to a moderate ſize, by nimbly licking, with the tip " of his tongue, a ſmall fragment of the ſtone, once every morning." To theſe he ſubjoins other ſtrange ſtories, which tho' I cannot believe, yet circumſtances will not let me reject. A gentleman in *France* was reported to poſſeſs ſome portion of this ſtone, and to have cured many inveterate diſeaſes, by ſuffering the patients to lick it; and my friend, Sir *Kenelm Digby*, who was then in that country, could not, upon inquiry, find this report to be fabulous. Beſides, *Helmont* not only relates theſe cures as an eye-witneſs, but ſays, that once ſuſpecting the virtue of this oil, he anointed it on the right arm and ancles of his wife, who had, for many months, been afflicted with ſevere pains in the former, and very great tumours in the latter; whereupon motion was immediately reſtored to her arm; all the ſwelling of her legs and feet diſappear'd; and ſhe continued healthful for nineteen years afterwards. And this relation, ſhe herſelf, long after the death of her huſband, confirm'd to our friend Dr. *C.* Theſe particulars receive confirmation from two remarkable circumſtances: for firſt, *Helmont* is the more to be credited here, becauſe he mentions cures not perform'd by himſelf, but by a ſecond perſon, and that too, with remedies unknown to him; ſecondly, our famous countryman, Dr. *Higgins*, who lived familiarly in the ſame houſe with *Butler*, gives a ſtrange atteſtation to his ſecrets.

But whatever be thought of *Helmont*'s relations, we have reaſon enough to conclude, that the power of nature and art may reach much farther than many diſtruſtful, not to ſay, indolent men have imagin'd; and, therefore, the prognoſtics, even of celebrated writers, are not to be relied on, when they aſſert that particular diſeaſes, or particular patients, are abſolutely incurable. The ſolid advice of that judicious author *Celſus*, deſerves a greater regard: " where " a medicine fails, ſays he, we are to reſpect the patient more than him that " invented it; and ſo proceed to try, firſt, one thing, then another."

SECT. IV.

The advantages of natural philoſophy to the hygieinal part of phyſic.

THAT the dietetical part of phyſic is improveable by natural philoſophy, appears in that our aliment requires art to direct its preparation, and order it to the beſt advantage. The inhabitants of *Barbadoes*, *St. Chriſtopher's*, and other *Charribbe* iſlands, ſupply us with remarkable inſtances hereof; where the poiſonous root *Mandiboca* is converted, as was formerly ſaid, into both bread and drink: being carefully freed of its moiſture by the preſs, dry'd in the ſun, and reduced into meal, it makes the former; and, by being chew'd, and ſpit out into water, it ſoon purges it ſelf of its noxious quality, and becomes the latter.

They

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They having in ſome of our *American* plantations, found it very difficult to make good malt of maiz or *Indian* corn, they firſt reduce it to bread, and afterwards brew a very good drink from it. And 'tis my opinion, that the malſter's art is capable of great improvements among ourſelves. *The different liquors of different nations.*

'Tis not in the knowledge of fermenting liquors, alone, that we are defective, but alſo of the materials wherewith they may be made. In *China*, they make their wine from barley; in the northern parts thereof, from rice and apples; but in the ſouthern parts, of rice only. The wine uſed by the common people will intoxicate, tho' faintly: 'tis made at any ſeaſon of the year, but beſt in the winter. In *Japan*, alſo they prepare a ſtrong wine from rice. We in *England*, likewiſe, have great variety of wines from cherries, apples, pears, *&c.* little inferior to thoſe of foreign growth. But to manifeſt our want of curioſity in this affair, 'tis obſervable that the drinks of one country are often unknown in another. The rice-wine of *China* and *Japan* is no where to be found in *Europe*; and beer or ale are eſteem'd great rarities in places where I have travell'd. The common drink in many parts of *Muſcovy*, and other northern regions, is hydromel, or water fermented with honey; and if a due proportion of theſe ingredients be obſerved, and the fermentation be ſkilfully order'd, ſuch a clear, ſtrong, wholeſome liquor may hence be prepared, as is not eaſily credited. In *Brazil*, and elſewhere, they make ſtrong wine of water and ſugar: and in *Barbadoes* they have many liquors unknown to us. Among the *Turks*, where wine of the grape is forbid by their law, the *Jews* and *Chriſtians* keep, in their taverns, a liquor made of fermented raiſins. And I my ſelf, by fermenting raiſins and water, in due quantities, without yeaſt, tartar, or any thing of like kind, have frequently, in few days, prepared a good vinous liquor, which afforded, by diſtillation, a large quantity of inflammable ſpirit.

I have ſometimes wonder'd, that men have ſo little curioſity to try what liquors are obtainable by wounding trees and other vegetables. The *Sura* in the *Eaſt-Indies* is made of the juice that flows from the cocoa-tree; and ſailors have often been inebriated, in that country, with the liquors made of the fermented juices obtain'd by the inciſion of vegetables. And that alſo in *Europe*, the nutricious juices of trees, as drawn from the earth, receive great alteration before they come to be aſſimilated, appears from the practice of the *Calabrians* and *Apuleians*, who, between *March* and *November*, obtain, by inciſion, from the common aſh-tree, a ſweet juice ſo like the manna, in that ſeaſon adhering to the leaves of the ſame kind of trees, that they call it *Manna del corpo*, trunk-manna; and uſe it ſucceſsfully. That this ſweetneſs proceeds not from the peculiar nature of the ſoil, appears in that 'tis alſo to be found in other places. To proceed: in ſome northern countries, the liquor that weeps out of the birch-tree is uſed as a preſervative againſt the ſtone; for which purpoſe *Helmont* highly extols a drink prepared thereof, with daucus-ſeeds and brook-lime. But the extraordinary effects I have ſeen of the liquor it ſelf in this caſe, and that when other remedies fail'd, occaſions me uſually to provide a quantity of it every ſpring. It may eaſily be preſerv'd by pouring oil on the top of it, or by diſtillation; tho' the beſt way is to impregnate it with the fume of ſulphur. I ſhould not be thus particular upon liquors, but that I ſuſpect, if a greater variety was made, and more ſkill uſed in

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their management, they might, by recruiting the ſpirits, and inſenſibly altering the maſs of blood, eaſily prevent and cure almoſt as many diſeaſes as our common ſophiſticated wines occaſion. For, in fermentation, the active and ſpirituous particles of vegetables being ſet looſe, and much better ſeparated from the groſſer, than by common diſtillation; they are incorporated with our aliment, and immediately convey'd, by the blood, to thoſe parts of the body, where their operation is required. Talking, one day, with a very learned and experienc'd phyſician about the nephritic virtue of wild carrot-ſeed; he told me, with a ſmile, that fermented in ſmall ale, he found its effect too great; for that he ſeldom heard of thoſe patients more to whom he had once preſcribed it.

But to leſſen our wonder at the efficacy of fermented liquors, we may conſider what virtue is aſcribed to a bare infuſion of tea; which among the *Chineſe* and *Japoneſe*, is the ordinary drink of perſons of quality; who value it ſo highly, that a ſingle pound of the *Japan* ſort is often ſold for an hundred pounds of ſilver: and no wonder, if it preſerves them from the ſtone and gout. I have been told, that, ſomewhere in the *Eaſt-Indies*, they make a drink of the raw fleſh of goats, capons, and the like; which, with rice and moloſſes, they add to a quantity of water, and diſtil, in an alembic, to a low ſpirit, call'd *Arrac*, which they frequently drink in hot weather, and find very cordial. Such a liquor, indeed, ſeems neceſſary to thoſe of that climate, in order to recruit their ſpirits, exhauſted by the exceſſive heat thereof; as the merchants travelling thro' the ſcorching deſarts of *Arabia*, *Perſia*, or *Turkey*, find it beſt to quench their thirſt with brandy, or the ſtrongeſt *Perſian* or *Spaniſh* wine. The neceſſity of ſuch a practice is alſo confirm'd by the concurrent teſtimony of ſuch of our own nation, as have travell'd in hot countries.

The preſervation of aliment.

Not only our liquors are improveable by natural philoſophy, but likewiſe the other parts of our aliment: it teaches us to make better bread than is commonly uſed, and diſcovers a better art of cookery than *Apitius* left us; that of pleaſing the palate without prejudice to health. Men, unaſſiſted by philoſophy, have gone far in preſerving food by excluding the air; which daily experience inform'd 'em contributed to its putrefaction. The learned Mr. *Borreel* lately aſſured me, he had eat biſket in *Holland*, which, being carried from *Amſterdam* to the *Eaſt-Indies*, was thence return'd good, by keeping it all the time in caſks well-calk'd and lined with tin. A friend of mine has alſo a way of preſerving fruit, for many months, by a bare artificial excluſion of the air. But it ſeems more difficult and uſeful to preſerve fleſh ſweet in long voyages, without ſalt, which is apt to occaſion the ſcurvy and other diſeaſes. The means whereby the ſailors do this, is, firſt to dreſs the meat, then cut it into ſlices; and laying them regularly one upon another in a cloſe caſk, they pour clarified butter thereon, to fill up all the interſtices; obſerving to keep the caſk cloſe cover'd. And I am not without hopes that a method will be found to continue even raw fleſh ſweet, by ſomething leſs corroſive than common ſalt. For not to inſiſt upon the curing of neats tongues with ſalt-petre; I have, for experiment ſake, kept a whole large puppy, for many weeks, untainted, in the midſt of ſummer, by bare immerſion, in a well-ſtopt veſſel of ſpirit of wine; and might, but for want of opportunity, have preſerv'd it much longer.

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And I queſtion not but water will aboliſh the taſte that the ſpirit communicates to what it thus preſerves.

Sugar is a thing but lately known in theſe weſtern regions: if we, therefore, conſider how many bodies the confectioners and others, not only preſerve by its means, but render grateful to the taſte, it will ſeem probable that expedients, yet unthought of, may hereafter be found for the ſame purpoſe. Many concretes beſides the ſugar-cane may, perhaps, be brought to yield a ſugar according to their reſpective natures: the *Indian* liquor, *Sura*, made from the juice of the cocoa-tree, by being evaporated and expos'd to the ſun, congeals into a ſugar, which tho', by reaſon of its brown colour, it be not much eſteem'd, yet a ſkilful naturaliſt might poſſibly improve it. *Garcillaſſus* alſo, treating of the fruit of a *Peruvian* tree called *Melle* or *Mulli*, tells us, "that "by rubbing it gently between their hands in warm water, they deprive it "of all its ſweetneſs; after which they ſtrain the liquor, and leaving it a few "days, to ſubſide, it becomes a very tranſparent drink:" He adds, "the "ſame, by boiling, becomes an excellent kind of honey." And that there is a great affinity between ſuch vegetable honeys and ſugar, appears from this paſſage of the diligent deſcriber of the *Brazilian* plants, concerning the *Caraguata*, or *Erva Baboſa*. "From an inciſion made in its ſhoots there flows "an immenſe quantity of liquor, whereof they make wine, vinegar, honey "and ſugar; for the juice, being naturally ſweet, is render'd much more ſo "by boiling, as well as thicker; ſo that, at laſt, it congeals to ſugar." Moreover, the governor of a colony in *North-America* aſſures me, there is in *New-England*, a kind of tree, exactly like our Walnut-tree, the juice whereof, that diſtils from inciſions, being gently exhaled, the remainder will congeal into a ſaccharine ſubſtance. The like was confirm'd to me by the Agent of the colony of the *Maſachuſets*. And, laſtly, an eminent planter in *America* told me, that "the ſtalks of maiz afford a ſweet juice, which, boiled to a ſyrup, gave "a flavour to tarts and other things, not diſtinguiſhable from ſugar." He added, that "both himſelf and others had in *New-England* made ſuch a ſy-"rup with the juice of water-melons."

To diſcover the wholeſomneſs or unwholeſomneſs of aliments.

Beſides the means already mention'd, we may hope to find out others to preſerve the health of men. The ingenious attempts of *Sanctorius* may furniſh us with new ways of diſcovering the wholeſomneſs or unwholeſomneſs of aliments. By the different weight of human bodies, upon uſing particular food, he obſerved, that pork, melons, *&c.* obſtructed inſenſible perſpiration, and were, by conſequence, unwholeſom. Tho', methinks, ſuch obſervations ſhould be carefully made and repeated various ways in different ages, ſexes, and conſtitutions, before they are eſtabliſh'd into aphoriſms. And this proceedure might enable us to prevent many diſtempers. Thus that aphoriſm of *Sanctorius*, "to "eat and drink more than uſual, once or twice a month, increaſes not the ſenſi-"ble evacuations, but renders a man lighter in the ſcale;" affords this important corollary, "A regular diet has not the advantage over a debauch committed "once or twice a month; becauſe the quantity taken in, excites perſpiration "to ſo ſurprizing a degree." And truly, experience teaches, that the promoting and ſuppreſſing of inſenſible perſpiration, whereby the body may, in a day, diſcharge four or five pounds of excrementitious matter, has a greater ſhare in

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in continuing health and cauſing diſeaſes than is uſually imagin'd: ſo that ſtatics, an art long thought uſeleſs to phyſic, may give us many uſeful directions relating to the preſervation of health.

Philoſophy helps to judge of the air, and water, as to their wholeſomneſs and unwholeſomneſs.

The naturaliſt can alſo deviſe means whereby to judge of the ſeveral kinds of aliment; and likewiſe of the temperature of the air of any place. Phyſicians generally ſuppoſe the light and pure water to be moſt wholeſom; ſo that an eaſy contrivance to know when water has theſe properties wou'd be of ſervice. We have been told, that water brought out of *Africa* into *England* was found, by common ſcales, to be ſpecifically lighter than ours, by four ounces in the pint. And as this kind of difference is eaſily found hydroſtatically, chymical experiments might be made to diſcover the reſpective qualities of different waters. Thus, many kinds of pump-water will not bear ſoup, and ſome will not dye ſcarlet or other particular colours. And I have often found an unſuſpected ſea-ſalt in water, by pouring thereinto a ſolution of fine ſilver, made in *Aqua fortis*: for as common ſalt, or its ſpirit, will precipitate the metal in form of a white calx, in ſuch a ſolution; I imagined, if the water had, in its paſſage through the earth, gained ever ſo few ſaline corpuſcles, they wou'd act, tho' faintly, upon the diſſolved particles of ſilver; and accordingly upon their mixture, a kind of whiteneſs immediately enſued. This experiment has taught me to avoid ſuch water, and to uſe in its ſtead, rain-water, or that which had been freed from its ſalt by gentle diſtillation.

Laſtly, natural philoſophy enables us to judge of the air, which is of the greateſt conſequence to the continuance of health; and to make farther diſcoveries therein, as to its wholeſomneſs or unwholeſomneſs in any place. And this *Sanctorius* teaches us how to eſtimate, from the weight of the bodies of the inhabitants. The late invention, alſo, of weather-glaſſes, manifeſts ſome of its properties. I ſhall only add here, that the various operations of different kinds of air upon certain ſorts of fleſh thereto expoſed; upon ſome fading colours; upon bodies apt to tarniſh or gather ruſt, *&c.* are more conſiderable than men ſeem hitherto aware of.

SECT. V.

The uſefulneſs of natural philoſophy to the therapeutic part of phyſic.

WE come now, in the laſt place, to conſider the therapeutic part of phyſic; whoſe improvement is, of all others, the moſt beneficial to mankind. I cannot, therefore, but wiſh that many phyſicians took more pains, than they do, to advance it. The deſign of phyſic is to relieve and cure the patient; and every part of the art is perverted, that does not conſpire to promote this end. "A witty phyſician being lately aſked, by one of the faculty, why, ſince his "patient grew worſe under languid remedies, he did not preſcribe him ſome-"thing more generous; adding, that otherwiſe he muſt neceſſarily die; the o-"ther briſkly reply'd, let him die if he will, ſo he die but *ſecundum artem.*" I hope there are few of this man's temper! 'Tis pity there ſhou'd be ſo many learned men who think a phyſician has done his duty, when, after a diſcourſe of the ſeat and nature of a diſeaſe, he foretels the event, and methodically applies a parcel of ſuch languid medicines, that he knows are as unable to cure

The neglect of phyſicians to improve their art.

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as to kill the patient. Such a dull proceedure as this, whereto ſome lazy or conceited practitioners confine themſelves, under pretence of its being ſafe, has expoſed the whole profeſſion to the cavils of empirics. The Lord *Verulam* tells us of one who uſed to ſay, "your *European* phyſicians are learned "men, 'tis true, but they know nothing of particular cures for diſtempers; ſo "that he compared 'em to biſhops, who have indeed, ſays he, the power of "binding and looſing, but no more." And Monſieur *Balſac* tells us of a phyſician at *Milan*, who boaſted he had kill'd a man by the faireſt method in the world. Such kind of ſtories are readily embraced, and turn'd to the diſadvantage of the profeſſion, by the greateſt part of mankind; who ſend for phyſicians, not ſo much to have their diſtempers methodically told them, as to be empirically cured of them. And truly, he who ſtruggles long with difficult caſes, has a much greater ſhare of my eſteem than he who would raiſe a reputation on the ſucceſs of his prognoſtics: it leſſens my value even for the great *Hippocrates*, that his talent lay chiefly this way. Who had not much rather have his friend's life preſerv'd by powerful remedies, than be told, for certain, the time he ſhall loſe it; or be ſhew'd in the open'd corpſe, the cauſe of his death? But I am to ſhew that this curative part of phyſic is improveable by natural philoſophy, and particularly by chymiſtry.

The uſefulneſs of chymiſtry to the curative part of phyſic.

As goodneſs is to be regarded before pleaſantneſs in a remedy, I ſhall not recommend the chymical preparations from their ſuitableneſs to take; yet phyſicians, methinks, ſhou'd be careful not to occaſion their patients more uneaſineſs by nauſeous medicines than is felt from the diſtemper; but cure them according to the old rule, *cito, tuto & jucunde*. The loathſomneſs of ſome phyſic will, moreover, cauſe it to be rejected before it can perform its intended operation; for which reaſon, I preſume, ſome phyſicians now uſe roſin of jalap rather than common purges. But chymiſtry may be farther uſeful to the practice of phyſic, by rendering evacuating medicines not only leſs nauſeous to the taſte, but leſs painful in the operation. Thus, mineral waters will work briſkly, without occaſioning ſuch ſickneſs and diſorder as are frequent upon taking the common pills or potions: and a preparation I make with ſilver, will, taken in a very ſmall quantity, pleaſantly evacuate ſerous humours; nor need the perſon be confin'd to his room who takes it. And medicines, will, I hope, be found to relieve patients without thoſe chirurgical operations of burning, cutting, and trepanning. *Helmont* ſays, "he knew a country fellow who cured all freſh "wounds by a drink prepared of burnt *Tilia:*" And I have more than once obſerv'd, that a ſcrophulous caſe was cured by *Paronychia*. If we may credit *Helmont* and *Paracelſus*, their *Præcipitatus diaphoreticus*, taken inwardly, cures cancers and the moſt inveterate ulcers: and if there be any truth in the relations of eye-witneſſes, phyſicians and others, as to the effects of the weapon-ſalve and ſympathetic powder, nature performs many ſuch cures with leſs pain than the chirurgeon. I knew, as I have before ſaid, a very ingenious man, poſſeſs'd of a powder wherewith he conſtantly undertook to cure the cancer'd breaſts of women, without any conſiderable pain; which I the rather believe it may do, becauſe it ſeems to me a dulcification of arſenic, fixt with nitre, and carefully freed from its corroſiveneſs, by repeated diſtillations, with freſh ſpirit of wine. *Bartholin* mentions the cures of ſome hurts in the head perform'd without trepanning,

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trepanning, where that operation was judg'd neceſſary. And that formidable way of ſtopping a hemorrhage from large veſſels by the actual cautery, would be needleſs, did we know ſuch remedies, as *Petrus de Oſma* mentions, in his letter to *Monardes*, dated from *Peru*. " In the city of *St. James*, ſays he, " lying in the province of *Chyle*, *Anno Dom.* 1558, there were ſome *Indian* " captives who cut off their own calves of their legs, which, for want of other " proviſion, they broil'd and eat; but the greater wonder is, that by apply- " ing the leaves of a certain plant to the wounds, the flux of blood was im- " mediately ſtopp'd." I know a rich man who had an uncommon fiſtula in his breaſt; and having, in vain, conſulted the ableſt chirurgeons of ſeveral countries, 'twas, at length, reſolv'd to trace it with the knife: whilſt they were preparing for the operation, a chirurgeon accidentally came in, and told the patient he could eaſily cure him without cutting; which he ſoon did, by the uſe of an almoſt indolent remedy; as the patient himſelf aſſur'd me; who, moreover, ſhew'd me his breaſt, and procured me ſome of the medicine. I ſhall here add, that a certain perſon having lately receiv'd a kick from a horſe; the phyſician and chirurgeon employ'd, concluded the part gangren'd, and the patient in ſo deſperate a ſtate, that they deſired to be excluded attending him: upon this, a large doſe of Sir *Walter Rawleigh*'s cordial was ſent him; he took it; his fever and delirium left him; and, to the ſurprize of every body, his limb was perfectly reſtored. As a confirmation of theſe relations, I ſhall produce what *Piſo* ſaw perform'd by the illiterate *Indians*. " Such gun-ſhot " wounds, ſays he, as, I remember, the *European* chirurgeons, both *Portu-* " *gueſe* and *Dutch*, thought incurable without amputation, were excellently " cured by the natives, with freſh-collected gums and balſams; and I can " farther teſtify, that by nothing but tobacco-juice they cured ulcers and mor- " tifications, which were given over in the hoſpitals."

Nor is rendering a cure agreeable, the greateſt advantage the art of healing may receive from chymiſtry; it may, likewiſe, aſſiſt to diſcover the qualities, both of ſimple and compound medicines. By its means we learn the predominant minerals in medicinal waters; tho' this is a ſubject that remains to be improv'd upon. And many trials have convinc'd me, 'tis rather our own, than the fault of nature, or of chymiſtry, that we remain ſo ignorant of medicaments: for tho' the abſtruſe properties of ſpecifics are not, I fear, eaſily learnt, without particular experiments and obſervations; yet many ſimples have unregarded qualities, ſuch as ſourneſs, ſaltneſs, corroſiveneſs, *&c.* reſiding in matter near of kin to ſalt, or ſulphur; whereby they frequently operate. And theſe qualities ſeem to be diſcoverable by chymiſtry, without making trial on the human body. There are ſome plants whoſe juices will coagulate into a ſalt, which may be call'd eſſential; and ſuch vegetables as theſe may be diſtinguiſh'd from others. And poſſibly, alſo, ſalts may differ in figure, taſte, *&c.* ſo far as to be diſtinguiſhable into different kinds. If, likewiſe, we compare the ſalts of theſe vegetables with thoſe of others, ſuppoſed to abound in volatile and ſaline parts; and, farther, examine other plants by chymical operations, whilſt we remark their diſpoſition to yield ſpirits or oils by fermentation, with other particulars, wherein they agree, or diſagree, with each other, 'tis very probable we ſhould make many

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many diſcoveries of their reſpective natures and properties*. The infuſion, or decoction, of ſome plants will become red by the addition of alkaline ſalts, whilſt acids will much impair, or deſtroy, that colour. A little *Aqua fortis* immediately turns the red tincture of brazil, made with water, into a pale yellow; a ſmall quantity of the lixivium of pot-aſhes, dropp'd into an infuſion of red roſe-leaves, changes it into a muddy colour; and a little ſpirit of ſalt, into a fine red. A very ſtrong ſolution of pot-aſhes will precipitate a part of the decoction of red-roſes; and upon filtring the mixture the groſſer parts will remain behind, like mud, of a dirty colour; but the liquor tranſmitted, appears high colour'd like muſcadine. As galls, a ſtiptic vegetable, afford a decoction, which, with copperas, makes the common ink; ſo other aſtringent plants may ſerve for the ſame purpoſe: for vitriol put to a decoction of oak-bark, or red-roſes, log-wood, or ſumach, will make a writing ink; but that all aſtringent vegetables will do the ſame, I cannot affirm. Obſerving that a ſolution of vitriol, and the decoctions juſt mentioned, precipitated each other, I diſſolv'd cryſtals of ſilver in water, which make a colourleſs liquor; and found they precipitated differently colour'd ſubſtances in the infuſion of ſeveral vegetables according to the ſeveral diſpoſitions thereof. Thus, alſo, *Saccharum Saturni*, whilſt diſſolv'd in the ſpirit of vinegar, that extracts it, being put to an infuſion of log-wood, *Lignum Nephriticum*, or red roſes, they will precipitate each other. Add to theſe, that ſulphureous oils, as *Oleum Tartari per deliquium*, dropp'd into the expreſſed juice of ſeveral vegetables, turns it, in a moment, to a lovely green, whatever be the colour of the vegetable. And tho' it be controverted whether quick-lime hath any ſalt that will diſſolve in water, or of what nature it is; ſome experiments therewith have ſhewn me, that the water thereof, well made, will precipitate a ſolution of ſublimate, and turn ſyrup of violets green.

I next obſerve, that alſo the medicinal qualities of animal ſubſtances are diſcoverable by chymiſtry; as we formerly ſhew'd by diſtilling the *calculus humanus*, how it differed from the ſtones of the earth. By diſtilling one parcel of crabs eyes, infuſing another in vinegar, and a third in white wine, perhaps ſomething peculiar to the nature of this concrete may be found. Nay, in ſome animal ſubſtances, the proper experiments will ſhew remarkable changes and properties, which are ſcarce perceptible to the eye. Thus I have remark'd in urine kept cloſe for many weeks, in a moderate heat, the virtues depending upon its volatile ſalt, will be ſo heighten'd, that whereas ſpirit of ſalt being added to freſh urine, they quietly mix; dropping the ſame ſpirit into digeſted urine, an hiſſing and ebullition will preſently enſue, and the volatile and acid ſalts ſoon after coagulate together into a third ſubſtance akin to ſal-armoniac. And ſo, tho' ſyrup of violets, diſſolved in a little freſh urine, ſeems only thereby diluted; a few drops of fermented urine, preſently change it to a deep green. Laſtly, the ſame digeſted urine dropp'd into a ſolution of ſublimate, immediately turns it white, by precipitating the mercury diſſolv'd therein.

* Here is an unexceptionable method chalked out for eſtabliſhing a *materia medica* upon a juſt foundation.

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To diſcover whether bezoar be genuine or adulterate.

The following experiment may afford a certain way to diſcover whether bezoar be genuine or adulterate. We took 40 or 50 grains of choice oriental bezoar, reduced to powder, and, in a bolt-head, poured on it ſix drams of good ſpirit of nitre, to try whether this liquor would prove a fit menſtruum for it, as we found it did for the *Calculus humanus*. And tho' this effuſion being purpoſely made in the cold, the liquor did not, at firſt, ſeem to work on the ſtone; yet, ſoon after, it fell violently upon it, and diſſolv'd the greater part of it, not without noiſe, and a great effervescence. The ſolution was almoſt red, and the glaſs being ſet in a digeſtive furnace, the whole powder not only diſſolv'd, but being left, for a night or two, in a north window, it afforded ſeveral ſaline concretions, much larger than could well have been expected from ſo ſmall a quantity of matter; and theſe cryſtals, whilſt they were yet in the glaſs, very nearly reſembled ſalt-petre.

The chymical analyſis of ſeed-pearls.

Two ounces of oriental ſeed-pearl, being put, whole, into a retort, and diſtill'd in a ſand-furnace by degrees of fire, giving a ſtrong one at the laſt; we obtain'd a little black oil, ſwimming upon the ſpirit, which was alſo dark and muddy, as if incorporated with ſome more oil. The weight of both theſe liquors was 23 grains, beſides which, there ſtuck, to almoſt all the upper part of the retort, a thin film of oil, which, together with a ſtreak of the like, reaching to the bottom of the receiver, we eſtimated at 3 grains more, and ſo reckon'd 26 grains for the weight of the whole aſcended matter. The *Caput mortuum* amounted to full the remaining weight of the two ounces. The empyreumatical liquors, that came over, ſmelt much like thoſe of harts-horn; and the ſpirit was found to belong to the tribe of the urinous ones, or of volatile alkalies; for it readily hiſs'd, and produced bubbles, with good ſpirit of ſalt, turn'd ſyrup of violets green, and being dropt into a ſolution of ſublimate, chang'd it white; the oil that ſtuck to the retort, and which was fetid, like that of harts-horn, eaſily diſſolv'd in rectify'd ſpirit of wine, and afforded a reddiſh brown ſolution. The *Caput mortuum* appear'd very black, and ſome grains of it were found readily diſſoluble in ſpirit of vinegar: being calcin'd in a well-covered crucible, with a ſtrong fire, it became purely white, and weighed leſs by ſome grains, than an ounce: and we alſo found, that being pulverized, it taſted hot and bitteriſh upon the tongue, like good quick-lime, and that it was not only of an alkaliſate, but a lixival nature: for it preſently turn'd ſyrup of violets green, and quickly afforded an orange colour'd precipitate, with a ſolution of ſublimate.

Mineral earths to be inquired after.

But farther, the naturaliſt may, by this kind of proceedure, increaſe the *materia medica*; for chymical preparations will diſcover that various bodies, not hitherto introduced into medicine, may be ſafely uſed; and that others, whoſe exhibition is attended with danger, may be more freely employ'd. Some chymiſts have lately made very good medicines out of zink, or ſpelter. It has often excited my wonder, to find phyſicians and chymiſts ſo negligent in diſcovering the qualities of mineral earths, and the like bodies that abound in moſt countries: for tho' they be look'd upon as ſtain'd elementary earth; I have, ſometimes, ſeen a great variety of them dug up in a ſmall ſpot of ground, ſo very different from each other in colour, taſte, conſiſtence, and other qualities, as to make it very probable their natures were different.

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The true bole-armeniac, and *Lemnian* earth, have been highly eſteem'd, both by ancient and modern phyſicians, as antidotes for malignant diſeaſes, and the plague itſelf; but as there are ſtrong ſuſpicions that theſe earths come to us adulterated, 'tis ſtrange phyſicians ſhould not try whether their own country cannot furniſh them with as good. The attempts lately made, might, one would think, encourage them herein. For, without crediting *Johannes Montanus*, the ſuppoſed inventor of the *Terra ſigillata Strigonienſis*, who affirms it to be tranſmuted gold; I find learned phyſicians prefer it to the *Lemnian* earth, that is brought from *Turkey*; particularly *Sennertus* highly recommends it againſt the plague, peſtilential fevers, the bites of venomous creatures, the diarrhea and dyſentery; he adds, that the chymiſts call it *Axungia ſolis*; which brings to my mind, that a gentleman once brought me a particular earth, found either in this, or ſome adjacent country, which, tho' it ſeem'd but a mineral one, afforded a conſiderable quantity of gold. They have, alſo, found in *Hungary*, an earth call'd *Bolus Tockavienſis*, ſaid by *Crato*, to melt in the mouth like butter; and, in other reſpects, to be like bole-armeniac; to which, he preferr'd it againſt catarrhs, and found its ſucceſs very great in the plague that reign'd in his time at *Vienna*. And a very learned and ſucceſsful phyſician of *England*, did lately, in peſtilential fevers, preſcribe, with a good effect, a red earth he found near the town where the plague raged. That experienced chymiſt alſo, *Johannes Agricola*, greatly commends the *Terra Sileſiaca* in ſeveral diſeaſes, and equals it to the beſt of *Turkey*; telling us, moreover, what ſeems ſtrange, that the ſpirit of it diſſolves gold, as well as *Aqua regia*, tho' more ſlowly, into a red ſolution, which in few days precipitates the gold in fine powder. The ſame author relates, that he has ſeen another earth, found near *Weſterwaldt*, in colour between white and yellow, preferable to the *Sileſian*, as yielding more ſalt than that; and diſſolving ſilver ſo much better than other menſtrua, as to render it potable, and parable into a uſeful medicine in cephalic caſes. Nor am I ſurprized at the efficacy of theſe earths, conſidering how they may be imbued with mineral fumes, or tinged with mineral juices, which, having never felt the fire, retain all their looſe and volatile parts, with a greater diſpoſition to communicate their virtues, than when reduced to a more fixed ſtate, or after the violence of the fire has thrown off their finer particles.

Chymiſtry may convert noxious medicaments into ſuch as ſhall be wholeſome.

Such mineral bodies as are, of themſelves, noxious, or unfit for medicinal uſes, may, by chymiſtry, be reduced to wholeſome medicaments, and ſo again enlarge the *materia medica*. Thus I knew arſenic brought, by ſalt-petre and ſpirit of wine, into a balſam, which, ſurprizingly cured a phyſician of my acquaintance, of dangerous venereal ulcers. And tho' biſmuth has not, till of late, been uſed but as a coſmetic; yet *Cloſſeus*, by calcination, and the addition of ſpirit of vinegar and *Cremor tartari*, makes two medicines thereof, which he highly extols in the dropſy. A chymiſt alſo, of my acquaintance, prepares it, with common ſublimate, into a white powder; a few grains whereof purge gently. Digeſtion, with powerful menſtrua, *&c.* may reduce the rankeſt poiſons to excellent remedies. And medicines thus prepared are highly extoll'd by *Helmont*. But tho' he ſpeaks in an hyperbolical manner concerning them,

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yet, when I conſider what great things are frequently performed by antimony, mercury, opium, even in the common preparations of them, it ſeems probable, that a more ſkilful management might thence obtain very extraordinary remedies. 'Tis ſaid, indeed, that when a poiſon is corrected, it thereby loſes its activity; but the ſimples above-mention'd, ſufficiently ſhew this not to be true, which are, by that means, prepared into ſafe and effectual medicines. Thus the bezoar mineral, wherein, when duly managed, the purgative and emetic quality of the antimony is changed into a reſolving diaphoretic and deobſtruent one, becomes a good medicine; and is well recommended by *Riverius*. Crude *Aſarum*, in like manner, known to be emetic, is very eaſily render'd diuretic, as ſome phyſicians aver, and ſerviceable in ſlow fevers. And that all other animal and vegetable poiſons may be corrected, without loſing their efficacy, is affirm'd by *Helmont* *. Crabs-eyes, reſolved into their original milky ſtate, he ſays, will do it in many vegetables; which was confirm'd from the experience of a phyſician of my acquaintance. Another, tho' no friend to *Helmont*, aſſured me he had ſeen vegetable poiſons, and, particularly, *Napellus*, ſo corrected by the volatile ſalt of tartar, as to become innocent. I ſhall ſay nothing here of *Helmont*'s *Sal circulatum*; but as to the volatilization of ſalt of tartar, my own experience perſwades me 'tis poſſible. 'Tis true, it muſt be a powerful corrector that can thus alter many different poiſons; yet I cannot ſee but ſeveral particular bodies may, by difference in the management, be prepared for medicinal uſe, without laborious or general correctives. Even lucky hits will, ſometimes, afford us theſe diſcoveries; as *Helmont* found that *Aſarum* loſes its emetic property, and becomes a diuretic, by boiling in common water; tho' boiling it with the ſame degree of heat in wine, will not aboliſh its native quality. I have known white hellebor, opium, *&c.* when duly prepared, given, with happy ſucceſs, in ſuch quantities as would, otherwiſe, have proved pernicious. The violent emetic and cathartic properties of antimony, are daily deſtroy'd by calcination, with ſalt-petre; corroſive ſublimate, by repeated ſublimation with freſh mercury, becomes a medicine that children may take with ſafety; and, even, that violent emetic, flowers of antimony, whoſe force the higheſt cordials are unable to abate, may, by bare heat and ſkill, be corrected, ſo that treble the common doſe ſhall only prove a gentle diaphoretic †.

Philoſophy will leſſen the expence of a cure.

Natural philoſophy brings another advantage to phyſic, by leſſening the expence of a cure. The end of medicine, 'tis true, regards men's health, and not their purſes; yet a phyſician, in equity, ſhould conſider the poor. To ſay

* To ſhew an eaſy way of converting poiſons into ſafe medicines, and afterwards how to apply theſe medicines as alteratives, occaſionally, would be greatly to ſerve mankind, and advance the art of medicine. Whoever has the ſecret of applying the ſtrongeſt medicines in due quantities, without promoting any ſenſible evacuation, and continues their uſe for the proper time, will, in chronical caſes, cure ſuch patients as others would be apt to judge incurable. One way of converting poiſons into ſafe remedies, is, to give them in very ſmall doſes, whereby their ſpecific virtue, as Dr. *Mead* obſerves, may be diſcovered. *Eſſays of Poiſons*, p. 132.

† *M. Homberg* knew a phyſician at *Rome*, who, even from real gall, prepared an excellent *Febrifuge*, which was ſo gentle as not to prove emetic. *Hiſt. de l'Acad. A.* 1703. p. 64.

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nothing of the extravagant fees given to the phyſicians of ſome places; the *Apothecaries* bills, in particular caſes, are ſo enormous, that after a recovery, the poor patients are often diſtreſſed to pay them. Hence it happens that the neceſſitous either languiſh without relief, or too late implore the help of a phyſician; whereas it were eaſy to preſcribe cheap medicines, that ſhould, at the ſame time, be efficacious. One way of doing this, is to avoid crowding a preſcription with ingredients; tho' I am not for exploding all compound medicines: for complicated caſes will, ſometimes, require ſeveral qualities in one remedy, which are not, perhaps, obtainable from any ſimple. And altho' the chief ingredient in a compoſition often demands correctives, a vehicle, *&c.* yet I am of opinion, 'twould be no detriment, were phyſicians more ſparing in beſtowing them. The addition of needleſs ingredients increaſes the bulk of a medicine, renders it more difficult to take, nauſeates the ſtomach, and prevents the efficacy of the more ſerviceable parts therein. 'Tis, moreover, a great impediment to the diſcovery of the virtues in ſimples, thus to huddle and confound them together; for when a number of ingredients are mix'd, 'tis impoſſible to know the operation of each. Again, tho' from exhibiting one of theſe complex medicines, a phyſician only expects an effect ſuitable to the ſingle quality predominant in the whole; ſeveral of the ingredients may have ſuch particular effects, as he never dream'd of; and excite the latent ſeeds of other diſtempers. Thus, I remember, an oculiſt told me, he had frequently found that parſly, accidentally uſed, either internally or externally, would cauſe great pain or inflammation, in ſore eyes; and my own were thus affected once by eating ſauce, wherein this herb was an ingredient. 'Tis ſaid, in favour of *theſe compoſitions*, that tho' ſome noxious ingredients enter them, they are ſo qualified by the reſt, as to become innocent: yet in venice-treacle, the ſame quantity of opium, tho' mixed with above ſixty other drugs, retains its virtue. And, perhaps, the reaſon why thoſe, who are continually taking phyſic, are uſually troubled with one diſtemper or other, is becauſe, by the variety of the medicines they uſe, ſuch humours are diſturbed, as might, otherwiſe, have lain dormant. But another argument for the uſe of compound medicines is, that how numerous ſoever the ingredients may be, they ſo temper and allay each other, that the reſult of the whole, is one chief medicinal quality. And, in ſome caſes, this ſeems probable enough; for a decoction of galls, and a ſolution of copperas, neither of which a-part are black, make ink by their mixture; as brimſtone, ſalt-petre, and charcoal, join'd in due proportions, compoſe gun-powder. Yet, tho' a new property ariſes, when a multitude of ingredients are added together, 'twill, I fear, be very difficult to determine beforehand what it will prove, whether noxious or harmleſs; or whether the principal parts ſhall be improv'd, or impair'd. Thus, tho' crude mercury, crude nitre, and crude ſalt, ſingly adminiſtred, even in large quantities, are innocent; yet a compoſition of the three makes a ſublimate, a few grains whereof will poiſon a man. Tho' I cannot, therefore, commend the uſe of thoſe famed compoſitions, mithridate, venice-treacle, and the like, when two or three ſimples might do as well; yet, becauſe long experience has ſhewn them to be good medicines in many caſes, they ought not to be neglected. But 'tis one thing to uſe ſuch a compoſition, after trial has proved

Compound medicines conſidered.

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proved it a lucky one, and another to rely on a huddle of ingredients, before experience has manifeſted the nature thereof. In a word, tho' I had no great opinion of the contrivers of the medicines, into which ingredients are thrown by ſcores, I would not reject an effectual one, tho' it prov'd ſo by accident, rather than deſign. A wiſe man may uſe a remedy, that none but a fool would have deviſed.

Another way to leſſen the charges of a cure, is to throw out of compoſitions ſuch ingredients as are unfit for the management directed. 'Tis not without ſurprize and indignation, that I ſee in the preſcription of phyſicians, and, even, in their public diſpenſatories, ſuch a want of ſkill in this particular. 'Tis uſual with them to order many things to be diſtill'd *in Balneo*, which, with that heat, will yield nothing, or only a little nauſeous phlegm; while the virtues of the ingredients, remaining behind, are often thrown away after the diſtillation is over. 'Tis, in moſt caſes, very unſafe to conclude the virtues of diſtill'd liquors the ſame, as of the ingredients they are made from.

Again, ſuch ingredients, as uſed ſeparately, would be effectual, are often ſpoil'd by an unſkilful mixture. I have ſeen many proceſſes, wherein ſaline ſubſtances of contrary natures are order'd; tho' there are ſcarce any bodies in the world more oppoſite to each other than acid ſalts, whether volatile, or fixed. Hence it frequently happens, that two good ingredients are deſtroy'd. And this is the caſe, when acid juices are order'd to be diſtill'd with alkaline ſalts; thus ſpirit of urine, and the ſpirit of ſalt diſtill'd together *in Balneo*, yield nothing but phlegm; leaving their active parts behind, coagulated into a fixed ſubſtance, a-kin to ſal-armoniac. In like manner, where active ſalts are made ingredients, unleſs judgment be employ'd in the compoſition, they frequently deſtroy one another's virtue, and degenerate into a new thing; and thence, perhaps, out of many uſeful ingredients, one bad medicine ariſes.

Many materials uſed in phyſic, have little virtue, and others neglected that have more.

The naturaliſt may further contract the coſt of medicines, by ſhewing, that many materials uſed in phyſic, have little, or no medicinal virtue, at leaſt not equal to the price they bear. I am not altogether for rejecting leaf-gold, and precious ſtones; the diſſolvent in the ſtomach, may, thence, poſſibly, extract ſome uſeful parts, and, thereby, render them ſerviceable to ſuch as will go to the price of them. I have, with different liquids, eaſily, and without heat, obtained tinctures from gems, and ſometimes diſſolved them: nor do I deſpiſe them exhibited in ſubſtance. Glaſs of antimony, which appears like a ruby, will readily impart an emetic quality to fluids; tho' as well rubies, as other gems, differ therefrom in fixedneſs. Gems will endure a violent fire, and the force of ſtrong corroſive liquors; but the glaſs of antimony yields to ſpirit of vinegar, and a ſtrong fire diſſipates it into fume. However, 'tis one thing to ſhew it poſſible for the human ſtomach to act upon gems and gold; and a different one to prove that it really does ſo, and by that means gets out the ſpecific virtues aſcribed to them. And were even this demonſtrated, it remains to be confirm'd, that theſe do more than cheaper ſimples: ſo that I ſuppoſe, phyſicians might do well to preſcribe the latter, whoſe virtue is unqueſtionable, to the poor, inſtead of the former, whoſe dearneſs is certain.

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What wonderful powers may reſide in the true *Aurum potabile*, I ſhall not now particularly inquire: the attempts, however, to make it ſo ſeldom ſucceed aright, that many have pronounced its preparation unfeaſible. But were it not; why muſt it poſſeſs ſuch virtues as others boaſt of? The current reports concerning it, ariſe, not from experiments, but in great meaſure the authority of books that bear fictitious names. And ſome, I fear, commend it, from a ſuppoſition that the gold is hereby rendered volatile, or exalted to a ſpiritual nature; and argue its excellence from the nobleneſs of the metal. But, for my part, tho' I have a menſtruum that will ſoon, with a gentle heat, bring over crude gold enough, upon a firſt or ſecond diſtillation, to afford a high yellow volatile tincture; yet as I can quickly recover a malleable gold therefrom, I dare not pretend to do wonders with the metal diſſolved therein. But to make an *Aurum potabile* in an hour or two's time without a furnace, or any other diſtilled liquor than rectified ſpirit of wine, I have ſeveral times prepared a ſaline mixture, conſiſting of one part of ſal-armoniac, two parts of roch-alum, and four of pure nitre. This, being well pulverized and mixed, I rubb'd diligently in a marble mortar with 15 or 16 parts, in weight, of the whole mixture, of leaves of gold; and placing the whole in a ſmall new crucible, with a few kindled coals around, at a ſmall diſtance from it, to neal the veſſel, I ſoon after ſet them nearer, till the heat made the matter melt; and with that gentle fire I kept it in fuſion till it viſibly emitted no more fumes, but grew dry again. Then preſently taking it from the fire, whilſt it was yet warm, I dug it out as clean as poſſible, and having ſeaſonably pulverized it, that it might not attract the moiſture of the air, I put it to ſome highly rectified ſpirit of wine, which within an hour or leſs was thereby enobled with a rich golden colour. And this I found by various trials, purpoſely made, to be a real ſolution of gold. And farther, to make a preparation, wherein gold is reduc'd to very minute parts, without the help of mercury, or of any precipitation by means of ſharp ſalts, we took refin'd gold, and diſſolv'd it in clean ſpirituous *Aqua regia*; and inſtead of precipitating the clear ſolution with oil of tartar *per deliquium*, ſpirit of ſal-armoniac, *&c.* we firſt, with a very moderate heat, drew off the ſuperfluous liquor, whereby the gold, with the remaining part of the menſtruum, was left in the appearance of a thick oily liquor. This done, we pour'd upon it a treble weight of vinous ſpirit, totally inflammable; and in a ſhort time we had a very ſubtile powder or high-colour'd calx of gold that ſubſided at the bottom; the menſtruum being ſtrangely dulcify'd as to taſte, and become fragrant in point of ſmell. A very few days after, we decanted the liquor and put on it freſh ardent ſpirit; when leaving them a while together, there ſubſided the like well-coloured calx, more plentifully than before; whilſt the menſtruum acquir'd ſuch qualities, as made it ſeem likely to prove an uſeful medicine.

Aurum potabile *prepared.*

This powder of gold, tho' it ſeem'd not to require it, we farther purified for internal uſe, by burning a totally ardent vinous ſpirit, twice or thrice thereon, to carry off with it any little corroſive or ſaline particles that might have ſtill adhered to the metalline ones.

The ſpirituous *Aqua regia*, here mention'd, which may probably be a more innocent menſtruum in preparing gold for medicinal uſes, I very eaſily make, by mixing one part of good ſpirit of ſalt with two of ſtrong ſpirit of nitre.

But

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But ſhould theſe, or the like preparations, poſſeſs medicinal virtues, they might, perhaps, be more owing to the menſtruum than the metal; whoſe nobleneſs depends upon the eſtimation of men, and is, accordingly, in ſome countries leſs eſteem'd than iron or copper. Nor, becauſe it is a fixed and precious body, muſt it therefore be an extraordinary medicine; for then diamonds wou'd hardly be ranked among poiſons. Be this as it will, 'tis abſurd that phyſicians ſhould prize ſimples, like drugſters, according to their dearneſs, or for coming from remote regions; as if God had made proviſion only for the rich, or thoſe who trade to the *Indies*. On the contrary, it frequently happens, as we before obſerved, that the *Caput mortuum* of the chymiſts, which is ſometimes thrown away as uſeleſs, may have greater virtues than thoſe reputed nobler parts, forced from the original bodies. And a deſpiſed common ſimple, nay an inſect or an excrement, may in ſome caſes prove nobler medicines than an extract, elixir, or a quinteſſence. Thus the ſuppoſed vile *Caput mortuum*, that remains after the diſtillation of *Aqua fortis* diſſolved in common water, yields a ſalt, which being only depurated by frequent ſolutions and filtrations, becomes the famous *Panacea duplicata*, or *Arcanum duplicatum*, purchaſed at the price of 500 dollars, by that great chymical virtuoſo the Duke of *Holſtein*; concerning which that prince's phyſician thus writes to *Schroder*: "Our court "has a thouſand times experienced the virtue of this ſalt, in hypochondriacal "caſes, continued and intermitting fevers, the ſtone, ſcurvy, &c. the doſe is "from one ſcruple to two." And another phyſician who frequented that court, aſſured me of the diuretic and deobſtruent quality of this medicine. But what appears more ſurprizing, is, that the *Caput mortuum* of vitriol, when all the oil is drawn out, and its fixed ſalt carefully ſeparated by water, the mere ſeeming *Terra damnata*, that remains, is parable into a nobler medicine, than, perhaps, either the oil, ſpirit or ſalt, of that mineral. That the bezoar-ſtone, ſold at an immenſe price, is every way inferiour in virtue to the *Calculus humanus*, we have the teſtimony of the experienc'd *Bontius*. And ſoot, tho' eſteem'd a vile commodity, is an uſeful one in phyſic. *Riverius* commends it in pleuriſies; and I have found that a ſpirit, made thereof, is no inconſiderable liquor. I know too that the medicines of ſome eminent phyſicians have the ſpirit of ſoot for their principal ingredient. I remember alſo an empiric of learning, who became very famous for curing difficult diſtempers of the brain, by a remedy he call'd his *Panacea*, or *Aurum potabile*, which, in exchange for another chymical ſecret, I learnt of him to be chiefly ſpirit of ſoot, wherein the flowers of ſulphur were ſo diſſolved, as to ſwim about in ſmall drops of a golden colour.

The Arcanum duplicatum.

The expreſs'd juice of ſtone-horſe dung will give relief in a ſuppreſſion of urine, to thoſe who are troub'ed with ſtitches or wind, and even in obſtructions of the liver and ſpleen. This homely remedy has, to my knowledge, been ſo ſucceſsfully uſed by a great lady, that ſhe prefers it to chymical eſſences and elixirs. And many of the poor were cured of the plague with the ſame, uſed as a *ſuccedaneum* to the powder of ripe ivy-berries, when that dreadful diſtemper lately rag'd in *Ireland*.

The medicinal virtues of human urine, both externally and internally uſed, require a volume to enumerate: and an induſtrious chymiſt has already made a collection towards it. An ancient gentlewoman, whom I knew, was adviſed

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viſed, for a complication of obſtinate chronical diſtempers, to drink her own urine every morning; which reſtored her almoſt to a miracle. A perſon of great quality went thro' the ſame courſe, after having found the *Spaw* ineffectual. And once I taught an empiric a cheap preparation of this excrement, which render'd him famous about the country, for the cure of many diſeaſes, eſpecially the pleuriſy.

Large quantities of wholeſome human blood are thrown away every ſpring and fall, as uſeleſs; yet by a ſkilful management it will, without any thing beſides ſpirit of wine to keep it from corrupting, eaſily afford a ſpirit and volatile ſalt, preferable, I believe to thoſe of harts-horn; for they have cured conſumptions, aſthmas, *&c.* to the admiration of my ſelf and others. To give one inſtance more, of the efficacy of things apparently deſpicable; the common wood-lice or ſows, which I have both taken my ſelf, and frequently recommended to others, are excellent, not only for the ſtone in the bladder, but againſt other diſtempers. A ſlight preparation of them was diſcover'd, by a learned phyſician, to be the grand ſecret of an empiric, famous in *England*, for giving relief in fits of the ſtone; and I knew an ancient gentlewoman ſkill'd in phyſic, who, having loſt the ſight of one eye by a cataract, had the ſudden loſs of that of the other foretold her by the oculiſts; but, to my ſurprize, ſhe continued to enjoy it in great perfection, by the help of millepedes infuſed in white-wine; which were recommended to her by a woman who had herſelf, thereby, been cured of a recent ſuffuſion in both her eyes. An ingenious phyſician, alſo, aſſured me, that he met with a woman in *Holland* who was cured of a real cataract by the juice of the ſame animals; being adviſed to uſe it by an empiric, reported to have therewith performed ſeveral cures.

Surprizing things have, alſo, been done in ſore and exulcerated breaſts of women by taking millepedes, bruiſed, in proper liquids; linen cloths being dipp'd in white-wine and applied warm to the part during the time of their uſe. Let me add, that I have ſeen a young lady who, by various fiſtulas in ſeveral parts of her body, was lamed, emaciated and weaken'd, to ſuch a degree, that her life was deſpair'd of; yet by the frequent uſe of a diet-drink, wherein millepedes were the chief ingredient, her ulcers ſpeedily heal'd, and a good habit of body was reſtored. And many other cures perform'd with the ſame medicine, were aſcribed to this ſingle ingredient. Another young lady I knew afflicted with a radicated epilepſy; who after numberleſs medicines, preſcrib'd by phyſicians, had proved ineffectual; and after her fits came upon her ſeverely, eight or ten times a day, was cured by the powder of true miſletoe of the oak, continued for ſome days, near the full-moon, in the quantity that wou'd lie upon a ſix-pence, every morning, in black cherry-water or beer. And tho' this remedy had ſcarce any viſible effect upon her; yet, after the firſt day it was taken, the fit never return'd but once. The perſon, who adviſed this remedy, profeſs'd he had therewith conſtantly cured that diſtemper, when he cou'd procure the genuine ſimple*.

* The uſe of this medicine is ſtill continued with tolerable ſucceſs; but many queſtion, whether it be a ſpecific for the epilepſy.

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To ſave trouble and charges in making chymical preparations.

To know how to ſave trouble and charges in preparing chymical medicines, is another way to leſſen the expence in the curative part of phyſic. It were wrong to ſuppreſs all chymical remedies becauſe of their dearneſs; for altho' a large price be paid for a conſiderable quantity thereof, yet a doſe may come cheap enough. There are alſo *Galenical* medicines ſold as dear, the largeneſs of their doſe conſider'd, as the chymical; yet when the prices of the latter are exorbitant, they ſhou'd be retrench'd. There are two things blameable in phyſicians as to this matter; firſt, their making uſe of chymical preparations, when ſimples or ſlight compoſitions wou'd ſerve as well; and, ſecondly, their beſtowing too much labour in preparations. There are phyſicians ſo fond of furnace-productions, that to cure a cut finger, they'll apply ſome chymical oil or balſam; and, in ſlight diſtempers, have recourſe to mineral remedies, or ſuch as, occaſioning great and unneceſſary alterations in the body, frequently do harm. Yet *Paracelſus* often uſed ſimples for the cure even of formidable diſeaſes. And tho' I am of opinion, that powerful or univerſal remedies are unobtainable without chymiſtry, and perhaps without minerals; yet I cannot but think, that ſimples, or cheap *Galenical* compoſitions, may cure moſt particular diſeaſes; and afford more noble ſpecifics than the chymiſts imagine. *Helmont* ingenuouſly confeſſes, "he believ'd ſimples, alone, ſufficient to "cure all diſtempers;" and ſcruples not to ſay, "there may ſometimes be greater "virtue in them, as they are afforded by nature, than as prepared by the fire." And, queſtionleſs, the ſpecific properties of many ſimples are deſtroy'd in chymical preparations. The moſt judicious chymiſts acknowledge, that pearls barely reduc'd to fine powder, are a better medicine than the magiſtery they make of them, by ſolution in acid ſpirits, precipitation with oil of tartar, and a careful edulcoration. The ſame is very obſervable in the magiſtery of harts-horn: for whereas, this ſubſtance, when crude, makes a jelly with water; the magiſtery remains a fixt powder, inſoluble even by acid menſtrua; and ſcarce affords any ſmoke when thrown upon a hot iron. I never found the vulgar chymical eſſences, or elixirs, half ſo effectual in ſtopping hemorrhages, as equal parts of hen-bane ſeed, and white-poppy ſeed, beat into a ſtiff electuary, with twice their quantity of the conſerve of red roſes. With this remedy, given in the quantity of a nutmeg, or walnut, both my ſelf, and others, have frequently cured profuſe bleedings at the noſe and elſewhere. Nor did I ever ſee ſuch ſurprizing effects from the moſt elaborate chymical preparations, in ſpitting and vomiting of blood, as from a ſyrup made only of plantain-juice, that of comfrey-roots, and fine ſugar. And unuſual cures of this kind have herewith been perform'd by two eminent phyſicians.

But I obſerved, that in caſes where chymical medicines are proper, the preparation thereof is too tedious and expenſive. A chymical proceſs is ſeldom order'd or eſteem'd, that requires not ſome weeks to complete it; as if the embryo wou'd otherwiſe prove abortive; or the medicine cou'd not cure with expedition, that was not ſlowly prepared. And this humour prevails, not only in making the ſtanding medicines of the ſhops, but even extends to thoſe deſign'd for extemporaneous uſes; and perhaps, for acute caſes too. Now, were a phyſician to wait till theſe remedies were made upon ſuch emergencies; his patients, I fear, wou'd, by that time, have little occaſion for them. Beſides, this tedioufneſs in the proceſs

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ceſs is often increaſed by the unskilfulneſs of the preſcriber. 'Tis frequent, we ſee, in chymical writings, to ſubmit the materials of the medicine to ſucceſſive operations; yet, were you to demand a reaſon for each ſtep taken herein, the operator might finiſh his proceſs before he cou'd give you a ſatisfactory anſwer. Nay, theſe proceſſes are ſometimes ſo injudiciouſly lengthen'd out, that the operations thwart or deſtroy each other; and leave the medicine in a worſe condition than 'twas found. And thus, as we juſt obſerv'd, the virtues in the common magiſteries are loſt. I lately met with a notable inſtance of this kind, in a famous modern chymiſt; who, to purify the fix'd ſalt of vegetables to its height, after numberleſs ſolutions, filtrations, and coagulations, orders it to be diſſolved in *Aqua fortis*; whereupon, ſays he, it will become very pure and cryſtalline, and not eaſily diſſolvable in the air. And truly, he is in the right; for, by adding *Aqua fortis* to ſome vegetable ſalts, and afterwards exhaling the ſuperfluous moiſture, I uſed to make good inflammable ſalt-petre. See with what judgment this ſolution was order'd, to depurate the ſalt the farther; and how fit ſuch authors are to be credited, in attributing to ſuch ſalts the improved virtues of the reſpective vegetables that yield them! In ſome caſes, 'tis true, as in making active and powerful menſtrua, exact depurations are neceſſary; but in many other caſes, ſuch as ſubtilization of a remedy, which often renders a proceſs incredibly tedious, is more inſignificant than chymiſts imagine; and ſometimes proves detrimental, by robbing it of thoſe fine parts wheron its ſpecific virtue depends.

Again, as a cure becomes more expenſive, thro' the charge of the ſeveral chymical operations whereby medicines are made; a farther acquaintance with experimental philoſophy, may ſuggeſt cheaper and better ways of performing them, than *thoſe* now uſed. And I queſtion not, but chymiſts may be inſtructed to make better *furnaces* for ſeveral purpoſes, than they are hitherto poſſeſs'd of; for the profeſſed artiſts among them, having been generally ignorant in other parts of learning, and particularly in mechanics; their furnaces and utenſils have never been contrived to the beſt advantage; with regard either to the huſbanding of their fire or fewel, or the intending and remitting its heat. 'Tis an agreeable ſurprize, to ſee how many veſſels may be duly heated by one ſmall fire, when the furnace is ſo contrived, that the flame may paſs thro' various windings to the vent. And as to the intenſeneſs of heat, I have ſeen odd effects thereof, without the aſſiſtance of bellows in a furnace capable of receiving but few coals; for I ſometimes vitrify'd even crucibles herein; and thought, by a ſmall alteration, I cou'd melt its ſides down. But a credible perſon, diſciple to *Cornelius Drebell*, cou'd do more than this. He aſſur'd me, he had a way of building furnaces, wherein he, by the ſingle force of the fire, made *Venetian* talc flow; which I confeſs myſelf unable to do by the fire of a glaſs-houſe. Experience, however, has aſſured me, 'tis eaſy to make a furnace give heat enough, without the leaſt help of bellows, to cupel both gold and ſilver. The heat in furnaces may alſo be better regulated than at preſent: and I look upon the ſkill of intending and remitting hereof at pleaſure, and particularly, of continuing it long in an equable degree, as a thing of greater moment, both to phyſic and philoſophy, than men ſeem appriz'd of. With lamp-furnaces, well order'd, many things may be perform'd

Philoſophy may ſuggeſt cheaper and better ways, than the common, of preparing medicines.

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form'd in imitation of nature; and several of my friends have, by means hereof, brought hen-eggs to manifest animation. That furnaces, also, may be so built, as to require but little attendance, appears from the obvious invention of athanors, or tower-furnaces; wherein the fire is, for many hours, supplied with a small quantity of coals, without ever burning much faster than is design'd: and that the labour of blowing may well be spared, and the annoyance of mineral fumes, in good measure, avoided, appears from those furnaces made with a pipe to draw the air, as in *Glauber*'s fourth furnace, or otherwise. I might add, that casting the materials to be prepared upon live coals, as *Glauber* orders, in his first furnace, is sometimes a cheap and expeditious way of preparing particular minerals; tho' his method, of making spirit of salt in that furnace, fail'd both with me and some of my acquaintance. There are, also, several other more commodious contrivances of committing things to a naked fire; so that, upon the whole, I cannot but expect, many good expedients of employing fire to chymical uses, will hereafter be found; which are not, at present, so much as dreamt of.

Surprizing things performed by chymistry.

And not only furnaces, but the vessels that immediately contain the materials to be prepared, are doubtless, capable of improvement. Those earthen retorts, called *Glauber*'s second furnaces, if made of good matter, may be render'd useful. The great convenience of sealing glasses hermetically, and of glass-stopples for bottles containing corrosive or subtile liquors, *&c.* persuade me, that, cou'd we prevail with the potters and glass-men to make their respective vessels according to direction, many things in chymistry might be made better and cheaper than they now are; and others perform'd, of which our present vessels will not admit. And as 'tis possible to render glass malleable, if that relation of *Pliny* and *Dion Cassius*, concerning an ingenious man who was put to death for it, be true; so, now chymistry is improved, cou'd this art be retriev'd, 'twould be very beneficial to mankind; by enabling us to make abundance of experiments which are now scarce practiable. Such an attempt must appear the more promising to chymists, because *Raymond Lully* expressly says, "it's one of the principal effects of the philo-"sopher's stone to make glass malleable*." And an expert chymist, not credulous, and, in a word, very well worthy of credit, assur'd me, that he had himself seen at *Mentz*, in the hands of a gentleman of *Switzerland*, a piece of glass, about the bigness of a shilling, which was red and transparent, like glass of antimony made *per se*, and which the owner affirm'd he had hammer'd in the presence of the elector of *Heidelberg*. But the *Switz* gentleman perceiving the other indispos'd to believe so strange a thing; after he had confess'd the glass to have been given him by an excellent chymist in his country, permitted him to lay the piece upon an anvil, and to strike seven or eight strokes with a hammer upon it; by which means he found, that tho' it was not malleable like

* 'Tis pretended, that the expression to make glass malleable, is a contradiction; since to be malleable, it must lose its transparency; that is, cease to be glass; for say some, how can its parts retain one certain order under the hammer; which alone fits it to transmit the rays of light? But, perhaps, this favours more of quibble than of argument, to chymical philosophers; who consider that glass in fusion, or in powder, is still glass: tho' even to these, I believe, the problem seems almost desperate.

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neal'd ſilver, ſince it began to crack at the edges like ſilver that is over-hammer'd; yet *it* did really ſtretch under the hammer; growing more thin on the beaten part, and having viſible marks or impreſſions made on it by the edge of the hammer. But as to my own opinion about ſuch a preparation, and the uncommon inducements I have for it, I muſt be here excuſed. However, as ſtrange things as this, ſeem to be performable.

Relating to a judicious perſon what a phyſician of *Bruxels* affirm'd to me, that he himſelf had prepared three or four reſuſcitable plants, one of which he preſented to the marqueſs of *Caſtel Rodrigo*, governor of the *Spaniſh Netherlands*, where this gentleman had lately been; he told me, that an apothecary of *Namur* really had prepar'd reſuſcitable plants in a different way from what others pretend to; and that he could prepare a great variety of them. And many of theſe, he aſſur'd me, he had ſeen preſerved in diſtinct glaſs-bottles; tho' the apparitions that were exhibited, ſhew'd not the peculiar colour, only the ſhape of the plant; but this ſo well, that he could perfectly diſtinguiſh, and eaſily know, the ſeveral plants; inſtancing particularly in *Carduus benedictus*, and camomile.

And the difference betwixt this way of exhibiting plants, and that mention'd by *Quercetan*; pretended to, alſo, by others; I found by this gentleman's anſwers, to conſiſt chiefly in theſe two things: the firſt, that the apothecary's plants did not, as the others, ſeem to grow up into the air included in a ſeal'd vial; but were ſeen growing in a clear liquor, wherewith the bottle, that contain'd it, was almoſt fill'd; and next, that tho' to make the apparition, mention'd by *Quercetan*, and others, the application of an actual heat is affirm'd to be requiſite, upon the abſence of which, the phantaſtical plant relapſes into its aſhes; in the formation of the apothecary's vegetables, he doth not employ any actual heat, but only the ſhaking of the bottle; for upon that agitation the prepar'd aſhes or powder being rais'd from the bottom, and diſpers'd quite through the liquor; when the glaſs is ſet by, in a quiet place, the ſcatter'd particles, by degrees, unite together ſo as to compoſe a model of the plant they once belong'd to. And heat not being requiſite to their formation, theſe plants do not quickly, as the *Polonian* phyſician's phantaſtic vegetable, recorded by *Quercetan*, fall back into a powder; but if let alone, continue till the preparer thinks fit, by a gentle agitation of the bottle, to diſſolve the looſe contexture *.

An ingenious perſon, very worthy of credit, inform'd me that he was employ'd, ſome years ago, by a *German* phyſician, to diſtil a certain known mineral, which he perform'd in a naked fire, with ſo good ſucceſs, that he had from about half a pound of the mineral, near three drams of liquor; which he included in a glaſs, with a bubble, and a ſlender neck, like a weather-glaſs; but

* There occur, ſays M. *Homberg*, many productions in chymiſtry, that, in ſome ſort, reſemble the vegetation of plants; but when cloſely conſider'd, they prove greatly different therefrom. Theſe productions are divided, by this author, *into* thoſe which conſiſt of a pure maſſy metal, without any other mixture; thoſe which conſiſt of a metal diſſolved in a menſtruum, wherewith it remains mixed; and, laſtly, thoſe which contain nothing metalline, only ſimple, ſaline, terreſtrial or oily ſubſtances. Of all theſe he gives ſeveral examples; with the proceſſes to make them; and the ſolutions of the phenomena therein. See *Memoir. de l' Academ.* A. 1710. p. 556,—572.

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tho' the liquor, at firſt, reach'd not above the bubble, only fill'd it to the bottom of the pipe; yet as the moon increas'd, this liquor, as the doctor expected, by degrees expanded it ſelf in the glaſs, ſo that about the full moon, it reach'd an inch into the pipe, and upon the decreaſe of the moon, it ſubſided by degrees to the bottom of the pipe. And when I ask'd, whether the veſſel were carefully ſtopt? he anſwer'd, that it was not only ſo, but hermetically ſeal'd, like one of my thermometers with ſpirit of wine; which he had ſeen. This the relator averr'd to me upon his own obſervation, and being deſir'd, he readily gave me a deſcription of the mineral, and a direction where to procure it; adding, that the ſame doctor made the like tryal with another mineral, a-kin to this; with which having heard that ſuch a thing had been perform'd, gave me occaſion to propoſe the queſtion.

Upon aſking an inquiſitive traveller, who lately waited on a *German* prince, addicted to chymiſtry, and was employ'd by him in his private laboratory, ſome queſtions about the ore of biſmuth or tin-glaſs, whereof there is ſaid to be a mine in that prince's territories; and in particular, whether he had obſerved any thing of the varying bulk of a ſtrange liquor obtainable from it; he anſwer'd, that he had made many tryals upon this mineral, and that particularly by his prince's command, he had diſtill'd a conſiderable quantity of a certain ſort of it; whereby he obtain'd a liquor, which being, by rectification, freed from its ſuperfluous phlegm, amounted to about half a pint. This liquor was put into a vial, which it almoſt half fill'd. This vial being exactly ſtop'd, was ſet aſide in a quiet place; where (according to the prince's expectation) as the light of the moon increas'd, from the new-moon, towards the full; this liquor gradually ſwell'd very manifeſtly and conſiderably; ſo that when the moon was in the full, the liquor reached almoſt to the top of the glaſs; and during her wane, as the light decreas'd, ſo did the bulk of the liquor, which was always leaſt at the new-moon. He alſo readily told me the way he uſed in making the diſtillation, which he ſaid, required an intenſe degree of fire.

An ingenious phyſician aſſur'd me, that at a place near *Amſterdam*, there liv'd a kind of a farmer, reputed very curious; who ſhew'd him, among other things, a conſiderable quantity of quick-ſilver wholly of the colour of gold; and that having purpoſely (with water) divided it into many globules, each of them retain'd the ſame rich colour. He farther told me, that the poſſeſſor of this yellow mercury, having put ſome over a fire in a convenient veſſel, it quickly loſt its fluidity, and was precipitated into a red powder.

Another very learned and experienc'd phyſician aſſur'd me, that an adept ſhew'd him a running mercury of a lovely green; which he purpoſely throw'd upon a carpet, and found the globules, whereinto 'twas by this means divided, to be of the ſame fine green that had beautify'd the whole maſs. But to return.

Several branches of chymiſtry improveable.

Spirit of wine, which is one of the moſt chargeable things in chymiſtry, requires, in the ordinary way, much time, and many rectifications, to clear it of its phlegm; but I have ſeen a veſſel, made of tin or pewter, invented by a chirurgeon, at *Paris*, that wou'd at one diſtillation, bring it over from wine it-ſelf, pure and moſt highly rectified. Nor do I queſtion, were the nature of fermentation

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mentation better underſtood, but inflammable ſpirits might be obtain'd from vegetable ſubſtances much cheaper than wine: for not only cyder, perry, *&c.* but grains, alſo, and berries, will yield it. In *Barbadoes*, they make their *Mobby*, a kind of wine, of potatoes: nay, ſuch a liquor is, likewiſe, obtainable from ſome ſorts of leaves; and I have found roſes, well fermented, to afford a good inflammable ſpirit. And, as to the preparation of pure ſpirit of wine, I have a way that exceedingly leſſens the time and trouble of rectifying it, tho' without any particular contrivance, either in the furnace, or glaſſes.

The naturaliſt, we hope, may, alſo, teach us good huſbandry in heating our furnaces, either by diſcovering new combuſtible materials, or introducing ſome cheap alterations in thoſe the ſeveral places afford; ſo as to augment, or render the heat more durable, and their ſcent leſs offenſive; or elſe by directing us to ways of performing with fire, what we uſually do by its means. In ſome countries, as here in *England*, where charcoal, alone, was formerly burnt in furnaces; pit-coal ſupplies its place. They who diſtil large quantites of *Aqua fortis*, do it with coals much cheaper than thoſe of wood: and, I find, that the ſame fewel may be uſed in other kinds of furnaces, where the bars of the grate are ſet wider; if a little charcoal be mixed therewith to promote its kindling.

And as pit-coal, of late, has been found among us, where it was before unknown, ſo, 'tis probable, other countries, were the proper ſearches made, may, alſo, afford the like. But the ſmoke of this coal being very offenſive, and other inconveniences attending its uſe; a way has been found to char and reduce it into coherent maſſes, of a proper ſize. 'Tis true, it is ſold almoſt as dear as *charcoal*; yet thoſe who conſume large quantities, find it near twice as cheap; becauſe it laſts much longer, and gives a heat far more intenſe than the other. It would, therefore, be a very uſeful thing in chymiſtry, to be able to char coals, without the uſe of thoſe pots whereto their preſent price is owing. And that this were eaſy to do, I ſhould directly ſhew, would it not prejudice the induſtrious chymiſt, whoſe invention it is. In *Holland*, likewiſe, they have a way of charring peat, a kind of turf, which might ſerve for fewel in chymical operations; tho' the manner of charring be not yet known in ſeveral countries, where perhaps, peat might be found. Nor is it improbable, that ſome places might afford combuſtible materials, which have hitherto no name aſſign'd them by minerologers. I have ſeen a ſort of coal, part whereof look'd like marcaſites, that burnt clear, and with a good flame, to whitiſh aſhes, without ſtopping the grate.

But as we improve in natural philoſophy, 'tis poſſible, ways may be found to excite heat, ſufficient for many chymical proceſſes, without the aſſiſtance of common fire, or fewel. Conſiderable heat is producible by the attrition of hard bodies, as iron and ſteel. And, perhaps, ſuch an heat might, by a cheap contrivance, as of a water engine, be produced in iron veſſels to digeſt with.

This I know, that from ſome ſucculent plants a liquor may be drawn by barely expoſing them, in proper glaſſes, to the rays of the ſun. The heat of horſe-

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horſe-dung, which chymiſts uſe for digeſtion, might ſerve to diſtil ſome fermented liquors; at leaſt, when augmented by a ſkilful addition of quick-lime and water. Many cheap materials, I doubt not, might, upon trial, be found to make portable digeſting furnaces, without fire, clear of the inconveniencies attending the uſe of horſe-dung. For not to mention the ſpontaneous heat in malt, and other ſorts of grain, and fermenting berries, I, many years ago, found that by ſurrounding glaſſes with refuſe hay, well preſſed, and uniformly wetted, it would for ſeveral days, afford ſuch an heat, as render'd that of horſe-dung needleſs: and yet the greateſt quantity of hay, that I ever employ'd for this purpoſe, was too little to take fire of itſelf; as ſometimes happens in ſtacks of it. And where actual fire is required, ſkill may leſſen the occaſions of it. To make ſpirit of freſh urine, near nine parts in ten are generally drawn off as phlegm, before the volatile part begins to riſe; but a knowledge of the nature of putrefaction, will ſave this expence of fire: for, let the urine ſtand, well ſtopp'd for eight or ten weeks, and the ſpirituous parts will ſo diſengage themſelves, that the gentleſt heat will raiſe them firſt, and leave the phlegm behind. And, even, from freſh undigeſted urine, I can, with eaſe and cheapneſs, make a ſubtile ſpirit riſe with a gentle heat, before the phlegm; only by pouring it upon quick-lime, juſt before diſtillation, 'till it riſe a few fingers breadth above the upper ſurface thereof.

The volatile ſalt of urine may eaſily be obtain'd with an exceeding ſmall degree of heat, barely by tempering the extract of urine with a convenient quantity of wood-aſhes; whereby the volatile part of the ſalt of urine is ſo freed from the groſſer ſubſtance, that it will, with ſtrange facility, aſcend fine and white to the top of very tall glaſſes.

To rectify that grand menſtruum, ſpirit of wine, you need only put about an inch thick of tartar, calcin'd white, and very dry, in the bottom of a tall, ſlender glaſs body, and pour thereon as much ſpirit of wine, once rectified, as will, when they have been ſhaken together, ſwim a finger's breadth above the tartar; and draw off the ſpirit with a gentle heat. This method ſaves the great expence, both of the time and charges, required in the common way of rectifying it; for even, what riſes laſt here will burn all away, yet leave only a mere phlegm behind, after diſtillation; and the ſame calx well dry'd, will ſerve more than once in this operation. And even, quick-lime, or ſalt of pot-aſhes, may here be ſubſtituted for the calx of tartar. Yet the ſimple ſpirit of good *French* verdigreaſe, being once or twice drawn from as much ſalt of tartar, as it can diſſolve in the cold, will leave the ſalt eaſily fuſible and diſſolvable in highly rectified ſpirit of wine.

'Tis farther remarkable, that I have gain'd an inflammable ſpirit from damaſk roſes, by beating them in a mortar, putting them into a veſſel, with a proper quantity of water and ale-yeaſt, and keeping them in fermentation for five or ſix days; and then diſtilling all *per veſicam*.

I alſo imagine, that menſtrua may be diſcover'd, capable of volatilizing, or unlocking the more groſs and ſluggiſh bodies, with greater eaſe than uſual. There is a liquor, uſed by chymiſts, with which I have often diſtill'd ſpirit

of

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of nitre, by a gentle heat of ſand; and believe could bring ſome over without any external heat at all. And having once ſuffer'd a certain menſtruum to remain, a very little while, upon crude antimony, I afterwards abſtracted it by a moderate ſand-heat; when the liquor brought over not only ſome of the ſubſtance, in form of red flowers, and united other parts thereof to itſelf, but rais'd ſeveral little tranſparent maſſes, like amber, to the top of the retort; which were inflammable, and both ſmelt and burnt like common ſulphur; and yet the menſtruum, which was eaſily recoverable from the antimony, only taſted, before 'twas uſed, ſomewhat like good vinegar.

But, beſides the ſeveral thrifty ways already mention'd, others, that are now unthought of, will, I queſtion not, by human induſtry, be diſcover'd. The calcination of gold and ſilver is render'd eaſier by amalgamations with mercury, than by the long continued violence of fire. And to lay no ſtreſs upon the *Alkaheſt* of *Helmont* and *Paracelſus*; I doubt not but menſtrua, to facilitate difficult operations, may be found; and ſuch as will not loſe their virtue, like our common ſaline ſpirits, by being but once uſed. The menſtruum I make by barely diſtilling good verdigreaſe, will ſerve ſeveral times to extract a tincture out of freſh glaſs of antimony.

To improve the means of preſerving medicines.

In the laſt place; a naturaliſt may, probably, find better means of preſerving chymical medicines than we now know. Clarified juices of vegetables, extracts, robs, &c. may be better and cheaper preſerv'd than by ſugar, if *Helmont* ſaid true, that he was maſter of ſuch an art. His way of fuming liquors with ſulphur, is a good one for this purpoſe. But a friend of mine has a ſecret to preſerve the fumigated juices of plants, with ſurprizing ſucceſs; his method is to add thereto a ſmall quantity of the white coagulum made by the pure ſpirits of wine and urine.

Specifics to be endeavour'd after.

'Tis tedious thus to inſiſt upon particulars; I ſhall therefore add, in the general, that the common practice of chymiſts, is no rule whereby to judge of the extent of the natural ſkill, and mechanical contrivances, that might be employ'd to render remedies more cheap, or which is the greateſt cheapneſs, effectual: for of all methods to reduce the expence of a cure, the uſe of ſpecifics is the beſt; and he who knows the true cauſes and ſeats of diſeaſes, is enabled to diſcover ſuch grand remedies, as bringing immediate relief to the patient, render the phyſician, chirurgeon, and apothecary, unneceſſary. Thus the merchant, formerly mention'd, was reliev'd, by a ſpecific, from the gout; one young lady cured of fiſtulas, by millepedes; and another of an almoſt hereditary epilepſy, by miſletoe of the oak, might ſeverally, in the ordinary way, have, in vain, beſtow'd an hundred times the money thoſe powerful medicines coſt them. But if ſlight medicines, or ſingle ſimples, may ſometimes, perform ſuch ſpeedy cures, even in chronical caſes; what may not be expected from the grand ſecrets of art and nature; when the beſt preparations of the nobleſt ſimples ſhall become known to judicious phyſicians, well verſed in the theory of medicine, and the hiſtory of diſeaſes? *Riverius* was none of the greateſt naturaliſts, or chymiſts; yet how many patients, according to his own

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account, did his ſpecific relieve from quartans, which might, otherwiſe, have prov'd no leſs tedious than expenſive?

The vulgar chimiſtry very incomplete.

But farther, the great variety of new remedies, to be found in the ſhops, will ſhew, that natural philoſophy may improve the pharmaceutical preparations of ſimples. I muſt, however, declare upon a ſerious conſideration, that the chymical medicines, which occur in the common diſpenſatories, are far from being the beſt that might be contriv'd. The vulgar chymiſtry remains very incomplete, and affords rather a collection of looſe experiments, than an art built upon ſolid principles: we muſt, therefore, expect a farther improvement herein, before the nobleſt ſort of chymical remedies become common; or conſiderable errors in ſeveral preparations be avoided.* 'Tis not labour, but skill, that produces noble medicines. A few pregnant principles, well applied, are more uſeful than many furnaces and glaſſes*. I never knew opium ſo well corrected by aromatics, and the tedious operations of the fire, as by wine and ſalt of tartar: and that violent emetic, *mercurius vitæ*, is better moderated, in its evacuating quality, by continual ſtirring it, in a flat glazed earthen veſſel, over a fire, 'till it emits no fumes, and turns of a grey colour, than by ever ſuch quantities of cordial liquors or conſerves. And this, as I am credibly inform'd, is the *Mecurius vitæ purgans*, ſo frequently mention'd by *Riverius*. And tho' quick-ſilver and antimony are by the ſafe practitioners, eſteem'd too churliſh to be meddled with ſingle; they may, together, be ſublimed into a cinnabar; which being alone, ſix or ſeven times reſublimed, becomes a ſafe and excellent alterative. I once knew a particular ſlight preparation of ſalt of tartar, correct ſuch poiſons, as, I am confident, ten times the quantity of the moſt powerful vulgar antidotes, would not tame. The ſame ſalt, duly managed, without proving either emetic or cathartic, has been found more effectual, in many ſtubborn caſes, than *Crocus metallorum*, *Mercurius vitæ*, or ſuch deſperate remedies. 'Tis a more remarkable inſtance, to our purpoſe, that chymiſts and phyſicians have not been able, with all their art, to deprive glaſs of antimony of its emetic quality; yet, this may eaſily be done, only by digeſting it with pure ſpirit of vinegar, 'till the menſtruum be highly tinged. And if you gently abſtract that liquor, and digeſt well rectify'd ſpirit of wine upon the remaining red or yellow powder, you will obtain an excellent tincture againſt ſeveral diſeaſes; which, tho' *Baſil Valentine* preſcribes only in a doſe of five or ſix drops; yet a domeſtic of mine, out of curioſity, took thirty drops at once, without finding it emetic. And I would here have it particularly remark'd, that by bare repeated digeſtions and fermentations, ſaline and ſulphureous eſſences, exceedingly ſmall in bulk, and durable, may be prepared from many vegetables. Some of theſe I have kept above three years, and they ſtill retain more of their

* That the obvious chymical operations may perform much more than is uſually expected from them, Dr. *Langelot* proves, by ſeveral examples; as the rendering of ſalt of tartar volatile, and diſſolving coral into a red mucilage, by digeſtion; rendering gold volatile, and gaining a genuine mercury from antimony, by means of trituration, &c. See *Philoſophical Tranſactions*, N°. 87. p. 5052.

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reſpective plants than the vulgar waters, ſpirits, extracts, or ſalts hitherto extant in the ſhops.

And, if we may believe the ingenious chymiſt to the *French* king, a ſingle herb, by pure ſkill, without the aſſiſtance of fire, may afford a nobler medicine, than any of the elaborate compounds, to be met with among vulgar chymiſts. This efficacious part of a plant, *Paracelſus* calls its *Ens primum*, whoſe proceſs, for obtaining whereof, I ſhould never have thought worth trying, but for what the experienced chymiſt, above mention'd, told me from his own obſervations: for he, as well as *Paracelſus*, aſcribes a renovating power to the *Ens primum* of baulm; and aſſur'd me, in the preſence of a famous phyſician, to whom he appeal'd for the truth of his relation, that an intimate friend of his, being poſſeſs'd of this preparation, made trial thereof, upon himſelf, by taking a ſmall quantity every morning, in wine, for a fortnight; long before the end of which he found the nails of his fingers and toes to looſen; which, at length, falling off, inſenſibly, he proceeded no farther; being ſatisfied with theſe tokens which he reſerv'd as a rarity. But upon giving the ſame medicine, for ten or twelve days, to a woman, about ſeventy years of age, without acquainting her with what he expected therefrom; it brought her menſes down upon her again ſo freſh, as to frighten her, and ſtop the proſecution of the experiment. He added, that he, alſo, gave ſome drops of it to an old hen, for a week; and about the ſixth day after, ſhe began to moult, and continued ſo gradually, 'till all her feathers dropp'd off; but regain'd new ones in a fortnight. My author, alſo, acknowledg'd, he had obſerved extraordinary virtues in the *Ens primum* of the greater *Scrophularia*.

His method was to collect the plant, at a convenient ſeaſon of the year, and proper time of the day, to beat it well in a ſtone mortar, and place it in a bolt-head, and to digeſt it for 40 days in a dung-hill; after which he opens the veſſel, ſeparates the groſſer parts of the liquor, and digeſts it in a gentle bath, that the remaining groſſneſs may ſubſide; then filtering the juice, he adds to it the fixed ſalt of the groſſer parts, abovemention'd, dry'd, and calcin'd. To this prepared liquor, he farther puts the liquor of good ſea-ſalt purify'd, melted, and ſuffer'd to run *per deliquium*. Then the whole, ſeal'd up in a convenient glaſs, is expoſed to the ſun, for about ſix weeks; after which there ſwims on the top of it the *Ens primum* of the plant, in a liquid form, tranſparent, and either green or red, or, perhaps, of ſome other colour, as the nature of the vegetable determines.

Helmont, alſo, has a way, which he calls *Via media*, very different from the vulgar one, of preparing *Elixir proprietatis*, whereto he attributes prodigious effects: ſome, indeed, think this method fraudulent; but, with care, I have made it ſucceed. And the medicine, itſelf, is given with great ſucceſs, in difficult caſes, by phyſicians of my acquaintance.

And here I cannot but obſerve, from conſidering the various alterations which chymiſtry brings upon natural bodies; and the many new properties it, therein, occaſions, that if we want not curioſity and induſtry, there muſt, hence, neceſſarily, ariſe ſuch a ſet of active and powerful medicines, as it were vain

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to hope for in apothecaries ſhops; and, conſequently, without any great diſcoveries, or farther improvement of principles, chymiſts, ſuch as they now are, may greatly add to the pharmaceutical part of phyſic. But if the operations of chymiſtry were ſtrictly examin'd, and thoroughly underſtood, there's no queſtion but, by a ſkilful application, and, eſpecially, by a rational and orderly ſeries thereof, many grand remedies are diſcoverable. Experience has inform'd me of a way, without any foreign matter, or violent heat, to reduce ſolid animal ſubſtances, almoſt wholly into a liquor, which, by a gentle fire, affords its ſpirituous and ſaline part before the phlegm. This, I would, in a particular manner, inculcate, that were we poſſeſs'd of a few ſafe, general, recoverable, and powerful menſtrua, 'tis not to be known, what might be done in chymiſtry: ſuch, therefore, as would advance chymiſtry, medicine, or natural philoſophy, would do well to turn their inquiries this way.

The ſearch after powerful menſtrua recommended.

An ordinary gold-ſmith can now, with *Aqua fortis*, make many uſeful experiments upon ſilver and gold, which none of the ſame trade, who liv'd before the diſcovery of that menſtruum, were able to do. No wonder therefore, that *Helmont* adviſes his readers to learn the volatilization of ſalt of tartar; the ſpirit whereof, he ſays, not only diſſolves crabs-eyes, ſilver, quick-ſilver, *&c.* but cures many diſeaſes. And by the concurrent teſtimonies of judicious chymiſts, this ſalt is worth labouring to obtain; tho' their attempts have all fallen ſhort of it. Notwithſtanding this, I cannot think the thing impoſſible; for I, more than once, with eaſe, render'd, even, gold itſelf, volatile, and exhalable, in time, by a vehement fire; and have, from crude tartar, mix'd with two or three mineral bodies, obtain'd a large quantity of true volatile ſalt; which I ſuſpect came from the tartar, tho' I muſt own, it was rather a volatile of tartar, than alkali of tartar made volatile*. This ſhews, however, that tartar, by an unuſual management, will yield an uncommon ſalt. Beſides, an ingenious acquaintance of mine, whom, notwithſtanding my great diſtruſt of chymiſts, I durſt credit, affirm'd to me, that he had ſeen a real volatile ſalt of tartar; wherewith ſuch ſtrange things were done, that he believ'd moſt of what *Helmont* deliver'd concerning it. And, I am inclined to think, this ſalt may be made by more ways than one; tho' a good method to volatilize it ſeems to be by ſpirit of wine; the difficulty wherein is to make them aſſociate. Now I have my ſelf, brought ſalt of tartar to flow readily upon a hot iron; to take fire, to flame, and when ſmartly dry'd, to diſſolve in highly rectify'd ſpirit of wine.

And, tho' many learned men are pleas'd to determine what can, and what cannot, be obtain'd in chymiſtry; no one ſhould be, thereby, diſcouraged from ſearching after theſe noble menſtrua. To my knowledge there is now in being a kind of menſtruum, of a pure cryſtalline ſubſtance made by fire,

* That judicious chymiſt, M. *Homberg*, has diſcover'd a way of volatilizing all manner of fixed ſalts. This he teaches by an example in his proceſs, for making his volatile narcotic ſalt of vitriol, from the *Caput mortuum*, after the oil is diſtill'd off. See *Memoir. de l'Academ. A.* 1702. p. 66.

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as truly ſaline as ſa't of tartar; which, tho' well purified, perfectly volatile, and eaſily ſoluble in rectified ſpirit of wine, as well as common water, and with either reducible to a noble menſtruum, is yet actually ſweet to the taſte. And, notwithſtanding the vulgar ſaline menſtrua, have actions contrary to each other, ſo that what an acid one diſſolves, an alkaline, or urinous one, precipitates; I have found, that a red tincture of glaſs of antimony, drawn with a menſtruum much lower than the former, could not be precipitated, either with ſpirit of urine, or an alkaline ſolution. Nay more, it readily mixed, both with theſe, and ſtrong acid volatile ſpirits, without the leaſt ebullition, or viſible effect.

The body of ſteel open'd in an extraordinary and uncommon manner.

We took ſeveral ounces of highly rectify'd ſpirit of fermented urine made *per ſe*, and pour'd it upon as much new filings of ſteel, as, we gueſt, would, at leaſt, ſuffice to ſatiate it fully. Theſe we put in a moderately warm place, where the menſtruum wrought on the metal for ſeveral hours together, and diſſolved a conſiderable part of it. This ſolution we ſet to filter, and found it of a taſte conſiderably ſtrong, but very different from any of the chalybeate preparations, we had ſeen made with acids. The liquor being kept in a ſtopt vial, for ſome days, near a window, did, in the cold, let fall, by degrees, a conſiderable quantity of powder, of a deep green colour, tho' the liquor itſelf was not of that colour; however, the ſuperficial part of what remain'd in the filtre, did, alſo, in the air, turn green. But tho' our ſolution, pour'd off from the ſubſided powder, was warily and ſlowly evaporated, we did not find it would well cryſtallize. What uſe may be made, in phyſic, of preparations of this kind, I leave thoſe of the profeſſion to judge.

To render ſteel volatile by a menſtruum, not ſo corroſive or dangerous to the body, as oil of vitriol, or ſpirit of nitre; I pitch'd upon good ſpirit of ſea-ſalt, and in ſeveral ounces of this liquor, diſſolved, as much as we eaſily could, of choice filings of fine ſteel; and having filter'd the green ſolution, we very ſlowly evaporated it in a glaſs veſſel, and took ſuch care not to ſpoil the matter, that we had plenty of fine green cryſtals; moſt of which we put into a ſmall ſtrong retort, and, by degrees, of fire, and a ſtrong one, at the laſt; we obtain'd many ounces of a liquor that came over in white fumes, like miſts driven by the wind, and afforded a ſulphureous ſmell. This liquor we rectify'd, and had a yellow ponderous ſpirit, that ſeem'd much nearer allied to the ſpirit of ſea-ſalt than to the common oil of vitriol; eſpecially, ſince being mixt with *Aqua fortis*, it would, like ſpirit of ſalt, make it, even without heat, diſſolve leaf-gold.

But having put into a little of it, already made yellow, by diſſolving leaf-gold, a very thin plate of gold, the menſtruum made it look all over white, almoſt like ſilver; which ſeem'd to argue, that this vitriolate liquor differ'd from common ſpirit of ſalt.

But the dry part, elevated by the force of the fire, we found to be diſtinguiſhable by its ſituation, and more durable accidents, into three kinds of ſubſtance; whereof one was almoſt like a powder, which, after touching the air, did, in a while, come to be of a yellow colour, almoſt like ſulphur; but it was not, indeed, truly combuſtible ſulphur. The other ſubſtance conſiſted of

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of larger parts, and was of a deep colour, between red and brown. But the third, which ſeem'd the largeſt of all, was made up of fine parts, bigger than the former, of a deep reddiſh colour, and adorn'd with a fine gloſs, like that of ſcales of fiſhes. The *Caput mortuum* was of a ſurprizing texture; for a great part of it appear'd to be turn'd into a talky ſubſtance, conſiſting of very thin broad plates, ſmooth and gloſſy, lying upon, and againſt one another, like thoſe that make up *Muſcovy* glaſs, when the pieces are more thick than large.

Gold debaſed by anti-elixir. Weighing two drams of gold, I cauſed it to be cupelled with a ſufficient quantity of lead, and quarter'd with refined ſilver, and purged *Aqua fortis*; then having brought the gold to fuſion, in a new crucible, carefully nealed, with the help of any addition; I put to it a ſmall quantity of a powder, communicated to me by a ſtranger; and continuing the metal a quarter of an hour in the fire, that the powder might diffuſe itſelf through it; we pour'd the metal into another crucible, gradually heated before to prevent cracking; where it was obſerv'd, at the firſt, to look like pure gold; and, afterwards, like an opal, for ſome time; yet, when cold, it appear'd to be a lump of metal of a dirty colour, and, as it were, over-caſt with a thin coat, almoſt like half vitrified litharge. To one ſide of the crucible a piece of metal ſtuck, almoſt like ſilver; and the bottom was over-laid with a vitrified ſubſtance, one part of which was tranſparent yellow, and the other of a deep brown, inclining to red; in which were five or ſix little globules, that look'd like impure ſilver. Having rubbed this metal upon a touch-ſtone, between gold and ſilver, the mark it left was more like ſilver than gold. 'Twas brittle, and being knock'd with a hammer, it flew into ſeveral pieces. The inſide reſembled bell-metal more than gold or ſilver. A dram of it, with about ſix times its weight of lead, being put upon a well-nealed cupel, emitted fumes, plentifully, for an hour and a half; and when the operation was ended, we found the cupel ſmooth, intire, and tinged with a fine purpliſh red; and, beſides the refin'd gold, there lay upon the cupel ſome dark colour'd recrements, which we judged to be baſe metal, but not lead. The gold being weigh'd again, had loſt ſeven grains in weight, which was made up by the recrement, whoſe weight and fixity were ſurprizing.

The dirty colour'd metal, being hydroſtatically weigh'd, inſtead of proving nineteen times as heavy as an equal bulk of water, it's proportion was but as fifteen, and two thirds to one; whence it appear'd that the gold was really debaſed, ſince it loſt, conſiderably, of its ſpecific gravity, an eſſential property.

From hence it appears, that an operation, almoſt as ſtrange as that called projection, may ſafely be admitted; ſince this experiment ſhews, that gold, which is ſo homogeneous, and the leaſt mutable of metals, may, in a ſhort time, be exceedingly changed, as to malleableneſs, colour, homogeneity, and ſpecific gravity, by ſo ſmall a portion of matter, that this powder tranſmuted a thouſand times its weight of gold.

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I now proceed to ſhew, that chymiſtry and philoſophy, as they ſupply us with medicines; ſo they may alſo greatly improve the *methodus medendi* itſelf. Medicine is ſo difficult, and ſo many things are neceſſary to a complete ſkill therein, that 'tis no ſcandal to phyſicians to ſuppoſe it improveable. *Hippocrates*, ſays *Paracelſus*, juſtly complains of the ſhortneſs of life, and the tediouſneſs of his art; and *Celſus* ſcruples not to call phyſic a conjectural art. No wonder it ſhould be hard to acquire, when the two great inſtruments of diſcovery in all arts, judgment and experience, are here, according to *Hippocrates*, difficult and dangerous. Many others, alſo declare, that the difficulties, of becoming a good phyſician, are almoſt inſuperable. 'Twill therefore, be the leſs ſurprizing, if we attempt an innovation in the curative part thereof; eſpecially, ſince I have obſerv'd the method of the beſt reputed phyſicians, in *England*, to be repugnant to each other. It certainly deſerves an impartial enquiry, whether the new diſcoveries made in anatomy and the doctrine of diſeaſes, ought not to alter and correct the old *methodus medendi*. Be this as it will, the uncommon efficacies of ſome new remedies may ſhorten the cures of diſeaſes, by anſwering many intentions at once. Thus the ſimple, I formerly mention'd, cured the king's-evil, without any other aſſiſtance; and thus phlebotomy is a remedy for the pleuriſy: tho' we have known it cured, even in young perſons, by chymical medicines alone. The rickets, ſuppoſed a new, and almoſt incurable diſeaſe, now commonly yields to *Ens Veneris*; tho' its operation be ſcarce ſenſible; bating, that at firſt it often proves diaphoretic. This gentle property, methinks, might lead phyſicians to conſider, whether they cou'd not frequently relieve their patients, without thoſe large and troubleſom evacuations they uſually preſcribe. For, the peccant matter is commonly ſmall in quantity, and might, were we maſters of ſpecific remedies, be either breath'd out by inſenſible perſpiration, or carried off by ſweat or urine without cauſing farther uneaſineſs to the patient. Great cures may be perform'd by bare external applications. Learned men aſſure us of the efficacy of the *Lapis nephriticus* againſt the ſtone, being bound upon the wriſts; and not only *Boetius de Boot* highly prizes it, but the famous *Monardes*, declares he has ſeen its great effects upon perſons of quality; which yet fall ſhort of what the learned *Untzerus* tells us about it. We muſt own, however, that ſome ſtones, which go under this name, have been unſucceſsfully applied in nephritic caſes: but it ſeems, that many of them, tho' not ſophiſticated, want this virtue, and are ſcarce, otherwiſe than by trial, diſtinguiſhable from thoſe of the good ſort, which are uſually greeniſh. *Garcias ab Orta* mentions a ſtone found in *Balagat*, called *Alaqueca*, that wou'd immediately ſtop any hemorrhage: and *Monardes* relates great virtues of another, againſt hyſterical diſorders. He alſo tells us, upon his own knowledge, of a blood-ſtone, found in *New-Spain*, that wou'd even ſtop the menſes, by being worn in a ring; and *Bontius* ſays of the *Lapis porcinus*, that it will cauſe abortion, and bring down the menſes, by being held in the hand. *Helmont* affirms he cou'd prepare a metal, whereof a ring being made, and worn, wou'd give inſtant relief in the hemorrhoids, and abſolutely cure them in four and twenty hours. He likewiſe commends it in ſuffocations of the uterus, *&c.* And if we may believe *Paracelſus*, he had a ring of ſtill more ſurprizing virtue. But to come

That chymiſtry and philoſophy may improve the methodus medendi.

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to other external remedies, *Fabritius ab Aquapendente* aſſures us, he cured a ſchirrous ſpleen, and the dropſy, by a continued uſe of ſponges dipp'd in common lime-water; and placed near the part affected. Add to this, the ſtrange cures related by *Kircher*, the like whereto have been confirm'd to me by eye-witneſſes thereof, concerning the cave near *Rome*, wherein the patients being expoſed naked, and thrown into a ſweat, either thro' fear, or the ſulphureous vapours of the place; are licked well by the ſerpents of the grotta. And do we not often ſee agues cured by amulets, and pericarpia? I my ſelf, after the uſual remedies had proved ineffectual, was cured of a violent quotidian, by applying to my wriſts a paſte made only of bay-ſalt, new hops, and blue-currants; which has, alſo, reliev'd many others both of quotidians and tertians; and done good ſervice in continual fevers.

That external remedies ſhou'd be farther tried.

I cannot help wiſhing, that phyſicians had been more curious, in trying the effects of external applications; for the ſubtile effluvia of ſome bodies ſeem, by this means, to inſinuate themſelves, without alteration, into the maſs of blood; and to have the ſame virtues as the body itſelf internally uſed. Thus it happens in ſome preparations of ſulphur; but more manifeſtly in cantharides and quick-ſilver, I was lately told, that by waſhing a child's ſcabby head with a decoction of tobacco, he was intoxicated, and made ſick; and that cathartics, externally applied, will operate. There are other medicines, which, before they get into the blood, receive great alterations from the ſtomach, *&c.* and may therefore have different effects, when externally applied. Thus it happens in the juſt mention'd inſtance, tho' neither the hops, bay-ſalt, or currants, taken inwardly, are noted for any febrifugal virtue. So likewiſe turpentine and ſoot are internally preſcribed in nephritic and pleuritic caſes; but externally, in pericarpia, againſt agues: and yarrow, beſides its other virtues, being worn in a bag, on the pit of the ſtomach, was the grand ſecret of a curious nobleman, in the ſame diſtemper. A very famous phyſician, alſo, aſſured me he had uſed it in the like caſes, with ſtrange ſucceſs. The chilblains, when they come to break, have been often cured by barely ſtrewing thereon powder of dried quinces. And who knows what effects other bodies, outwardly uſed, may produce, were experiments properly made to diſcover them? The internal operations of ſome things, are directly contrary to their external. Spirit of wine, applied outwardly, allays inflammations on the ſurface of the body; which if it were drank, wou'd inflame; and the poiſonous juice of the root mandihoca, *Piſo* tells us, is good for ſore eyes. Beſides, were the ſimples, deſign'd for external application, ſkilfully prepared, it might greatly improve their operations. Vitriol, which is copper, or iron, corroded and fix'd by acid ſalts, has virtues not to be found in thoſe metals when crude. Gold diſſolved in *Aqua regis*, and precipitated by oil of tartar, is, taken at the mouth, a gentle purgative; but the ſame preparation, calcined with flowers of ſulphur, becomes diaphoretic. And tho' the external virtues of this medicine be not much commended, 'tis probable they are very great, and different from thoſe it has when uſed internally. I knew a perſon greatly afflicted with ulcerated hemorrhoids, who applied thereto an ointment, that chiefly conſiſted of this *Aurum fulminans*; and tho' at firſt it occaſion'd exceſſive pain; that ſoon abated, the hemorrhoids cloſed

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cloſed the day after, and totally diſappear'd on the following; nor has he now, for ſeveral years, had any relapſe. The phyſician, who accidentally directed this, aſſured me, he had found ſtrange effects therefrom in venereal ulcers. The phlegm of vitriol, and *Saccharum Saturni*, which, given internally, are ſaid to cool the blood; and externally applied, to cure burns and inflammatory tumors, do both, nevertheleſs, diſcuſs cold ſwellings.

A famous chymical writer aſſured me, his child was ſo ſtrangely and deſperately affected, that he concluded him bewitched; but upon ſuſpending the *Electrum mineraie immaturum Paracelſi* about the child's neck, ſo as to touch the pit of his ſtomach, he immediately went to reſt, which he had not done for many days before; and, waking, cried for the breaſt, and, from that time, ſuddenly and ſurprizingly recovered. I am not forward to credit relations about witchcraft; but let what will be the diſtemper here, 'tis plain that a cure of a bad caſe was ſoon perform'd by the external application, even of a mineral ſubſtance.

Boetius de Boot records ſome very remarkable effects of the blood-red jaſper-ſtone. "Tho' I am not fond," ſays he, "of attributing extraordinary virtues to "gems, yet am I an eye-witneſs of ſome ſtrange effects of the jaſper. A maid "having her menſes continue ſo obſtinately, for ſome days, that nothing cou'd put "a ſtop thereto; I ordered her to bind a red unpoliſh'd one to her thigh, which "immediately cured her. Another perſon, receiving a wound in his foot, there "enſued ſuch an hemorrhage as we could by no means reſtrain, till this ſtone "was applied; which inſtantly ſtopp'd it, tho' the wound remain'd uncover'd." But the moſt ſurprizing relation he gives us, is concerning the maid at *Prague*, who had a vehement hemorrhage continue upon her, ſeveral times in a week, for ſix years together; and no remedies reliev'd her. Our author, therefore, lent her an experienc'd jaſper, which when ſhe hung about her neck, the flux of blood immediately ceaſed. She afterwards wou'd, out of curioſity, lay aſide the ſtone; when the hemorrhage, in a few weeks, conſtantly return'd; which ſhe as conſtantly ſtopped by putting it on again. At length, however, ſhe was quite cured hereby.

The experienc'd *Henricus ab Heer* mentions a ſtill more ſurprizing effect of an appended remedy. He tells us, that a woman who had, by an unſkilful midwife, her bladder ſo lacerated, that ſhe was ſubject to a perpetual diabetes, found a cure by wearing, as a gypſy taught her, a little bag hung about her neck, wherein was included the powder of a toad burnt alive in a new pot. I the rather mention this, becauſe the author found the ſame effectual upon a merchant, who was left, in a like condition, by an unſkilful lithotomiſt; and becauſe, recommending this odd remedy to the tryal of a curious phyſician, he told me, tho' it had failed in one or two inſtances, it had ſucceeded in two or three. He added, that in one, whoſe diſtemper proceeded from a dilaceration of the bladder, the remedy did ſervice, as long as ſhe wore it about her, and kept it renewing, as its virtue diminiſh'd; but if ſhe left it a while, the diſtemper return'd.

Henricus ab Heer, alſo, tells us of a lady, a patient of his, whom he ſuppoſed bewitch'd, and thought incurable, till he met with an unguent, in *Carrichter*, a *Dutch* author, extoll'd for this purpoſe, which proved effectual. I my ſelf have met with the preſcription, in this author, ſet down a little different from what I

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find it in the former. The miſletoe of the hazel, an ingredient herein which *Henricus ab Heer* found great difficulty in procuring, is not ſo ſcarce in *England*, being very green and extremely bitter; I, therefore, wiſh thoſe who have opportunity, wou'd make trial thereof; for beſides the above-mention'd authorities, a learned phyſician highly commended it to the judicious *George Horſius*.

Now, tho' we ſuppoſe theſe caſes not to be ſupernatural, or the effects of witchcraft, there muſt be a wonderful efficacy in an external remedy, to cure, by barely anointing the limbs therewith, ſuch radicated diſorders, with their horrid train of ſymptoms. 'Tis the leſs ſtrange, therefore, what *Helmont* ſays of a plaiſter, wherewith he infallibly cured even autumnal quartans, and prevented a relapſe, which was compoſed only of a few reſolving and abſterſive ingredients; he adds, indeed, that it ſucceeded more ſlowly in fat perſons. And yet, in theſe approved methods of curing diſtempers, there is no ſenſible evacuation made of the peccant matter, which, perhaps, ſtill remains in the body; being only deprived of its former qualities, by the effluvia of theſe remedies, and thereby render'd ſo far obedient to nature, as to be thrown off, if neceſſary, either by ſweat, urine, or inſenſible perſpiration. That a diſeaſe may, ſometimes, ſeem to be remov'd, whilſt the peccant matter is lodg'd in the body, appears from the cure of agues by a ſudden fright; wherein no diſcernible evacuation is made; tho' probably ſome change in the fluids, or texture of the morbific matter, be thereby occaſion'd: this ſeems confirm'd by many inſtances already produced. I knew a couragious officer in the army, who was ſtrangely fearful of rats; and having been long tormented with an obſtinate quartan, he carried it with him into ſeveral countries, without finding a cure. Coming at length, by accident, into a room, where an huge rat being up in a corner, and cou'd not, otherwiſe, eſcape, furiouſly leapt upon the gentleman; which put him into ſuch a fright as freed him from his diſtemper. *Salmuth* relates a pleaſant cure, even of the gout, by a fright. A gouty perſon having his feet and hands wrapp'd up in a cataplaſm made of turneps, flower and milk, happen'd to be left, alone, in his chair, when a ſow, invited by the ſcent of the ingredients, came into the room; and, endeavouring to get at the poultis, overthrew the gentleman and his chair; which put him into ſuch a fright, that his pains decreas'd, that very day, and afterwards continuing to diminiſh gradually, they at length totally left him, and never return'd.

Diſeaſes cured and cauſed by frights.

A woman, of a middle age, told me, that taking her ſon, a little boy, whom ſhe was dotingly fond of, with her to a river-ſide; whilſt ſhe was buſy, the child ſtole away from her, and walking along the bank, he chanced to fall into the river: in the mean time, the mother, miſſing her child, haſtily caſt her eyes towards the brink of the river; and, not ſeeing him there, preſently concluded him drown'd; and, upon that, was ſtruck with ſo much horrour, that, among other miſchiefs, ſhe fell into a dead palſey, of her right arm and hand, which ſtill continued, notwithſtanding all ſhe could do to remove it.

I familiarly knew a gentleman, who, when he was a youth, fell into a violent and obſtinate ſciatica, which continued with him ſo long, as to leave him little hopes of relief; but the devotion of his friends cauſed him to be carry'd, ſince he could not go to church upon ſundays; and here it happen'd, that the town being a frontier garriſon

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garriſon, there was occaſion given of a very hot alarum, that the Enemy, being got into the town, was advancing towards the church, to maſſacre all that were in it. This ſo amaz'd and terrify'd the people, that, in very diſorderly haſte, they ran all out of the church, and left my friend in his pew; who being no leſs frighten'd than the reſt, forgot his diſeaſe, and made a ſhift to get off, and follow thoſe who fled; but it quickly appearing that the alarum had been falſe, his friends began to think in what a condition they had left him; and haſtening back to help him out of the pew, they, to their great ſurprize, found him in the way upon his feet, and walking as freely as other men. When he told me this ſtory, it was above forty years ſince the thing happen'd; and in all that time he never had one fit of the ſciatica.

There are various inſtances of great changes produced in the body, when nothing has been receiv'd at the mouth. On the other hand, a good air, alone, does frequently, in conſumptions, and other diſeaſes, perform what was, in vain, expected from phyſic. 'Tis pity our *European* phyſicians ſhou'd want the phyſic books of *China*. The famous Jeſuit *Samedo* informs us, that the writings of our phyſicians having not yet reach'd *China*, phyſic is there learnt from their own numerous authors. And tho' phlebotomy be not practiſed, either there or in *Japan*, and tho' they uſe neither cupping nor iſſues, ſyrups or potions, and nothing but ſimples; yet phyſic, ſays our author, is in a very good ſtate amongſt them; and, accordingly, he gives us ſome conſiderable inſtances of their ſkill therein. 'Tis true, their phyſicians are, in point of learning, much inferiour to ours; but methinks, 'tis ſomewhat extraordinary, that in ſo vaſt, civilized, and populous a country, phyſic ſhou'd be ſucceſsfully practiſed, without the uſe of thoſe evacuations, which are ſo frequent among us. 'Tis, alſo, probable, that medicinal knowledge is greatly improveable, by more curiouſly obſerving the practice of midwives, and barbers, the good women, and empirics, with the reſt of that illiterate crew, among our ſelves, who preſume to meddle with phyſic; as well as of the *Indians*, among whom the generality of men are ſo ignorant, as to live without phyſicians. For where phyſic is practiſed without any knowledge of the art, many things are raſhly done, which may afford good hints to a judicious obſerver. Not to mention, that where phyſicians are illiterate, ſpecifics generally flouriſh; for ſuch perſons, for want of ſkill in pharmacy, and knowing how to vary their remedies, as circumſtances require, almoſt wholly rely upon ſpecifics; the virtues whereof are uſually more obſervable in their practice, than in that of more ſkilful artiſts; becauſe empirics having their ſole dependance upon theſe, they try them to the utmoſt, without mixing, as is too common, other ingredients therewith; which, as *Galen* well obſerves, will render it difficult to determine what it was, in the compoſition, that did either good or harm.

Bontius tells us, 'tis undeſervedly, that the *Europeans* eſteem the *Indians* as barbarians. He ſays, the moſt unlearned among them have a perfect knowledge of plants. *Linſchoten*, alſo, ſays, that the phyſicians of *Goa*, not only cure thoſe of the natives, but the *Portugueze* themſelves: he adds, that the vice-roy, with the arch-biſhop, and all the eccleſiaſtics, put more confidence in theſe, than thoſe of their own nation. In confirmation hereof, I might alledge the practice of the uncivilized *Iriſh*, and ſome other countries, where profeſs'd phyſicians are

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unknown. But, as *Celſus* ſays, "this art is practiſed univerſally, and the moſt "ignorant nations have their plants and remedies for wounds and diſeaſes." I, therefore, wiſh, that others would imitate the example of *Proſper Alpinus*, who wrote the *Egyptian* practice of phyſic; of *Bontius*, who treated of the *Indian*, and of *Piſo*, who, lately, gave us the rude method of the *Braſilians*; wherein he tells us, there are many things, which may inſtruct the moſt learned phyſician: and, according to the ſaying of our great *Harvey*, "there is no nation ſo barbarous, "but, either by accident, or abſolute neceſſity, may find ſomething of uſe to "mankind, whereof the politer nations are ignorant." Nor ſhould we deſpiſe remedies found by ignorant people, becauſe they know not our theory of phyſic. The empirics, in *Celſus*, wittily ſaid, "does reaſon agree with, or does it "contradict experience? If the former, 'tis ſuperfluous; if the latter, 'tis falſe." Let uſeful remedies come from what quarter ſoever, they are not to be rejected; be the ignorance of thoſe who preſent them, ever ſo great, or their opinions ever ſo contrary to ours. "Reaſoning, ſays *Celſus*, has nothing to do with "phyſic; the defences of oppoſite opinions may cure diſeaſes alike; and this, "becauſe they, therein, follow not their obſcure hypotheſes, but experience, "that gave birth to the art." This paſſage, indeed, aſcribes too little to reaſon, yet there is ſomething remarkable in it; eſpecially, if we conſider, that the late diſcoveries of the motion of the chyle, and lymphatic juice, hath not yet enabled men the better to cure diſeaſes. Anatomical diſcoveries may, perhaps, in time, greatly conduce to improve the curative part of phyſic; yet this obſervation may give us a caution againſt relying upon the diſputable opinions of phyſicians, ſo far as to contemn all the practice that does not ſquare therewith. Our author ſays well in this caſe, "diſputation may be here continued for both ſides "of the queſtion, where wit and eloquence, at length, will carry it; on the con- "trary, 'tis not oratory, but remedies, that cure diſtempers." It would be tedious here to cite all the authorities I am able, to confirm the efficacy of external remedies; there is one, however, that muſt not be omitted: 'tis in a letter written from *Peru* by *Petrus de Oſma* to *Monardes*. "There was an *Indian*, in the "city *Poſto*, where I reſided ſeveral years, who cured all diſtempers by the juice "of a ſingle plant, rubbed upon the affected parts. But covering his patients up "cloſe, he cauſed them to ſweat, when pure blood would flow from the places "whereon the juice was rubbed; this he wiped off with linen, and continued the "operation, as long as he thought proper; in the mean time ſupporting them "with a nouriſhing diet. By this means, many deſperate caſes were cured; "and ſo well too, that the patient ſeem'd to be thereby render'd ſtronger and "younger: but we could not, by all our art, prevail upon him to diſcover to us "the plant."

Magical cures to be enquired into.

There is another ſort of external remedy, which pretends to operate in a ſtill more wonderful and extraordinary manner; whereinto it might be proper, cou'd we avoid credulity, to enquire. And it might, pehaps, deſerve an experiment, to ſee whether ſuch cures, as vulgarly paſs for fabulous or magical, are actually performable: ſuch are thoſe reported of the weapon-ſalve, and ſympathetic powder, *&c.* ſaid by chymiſts to be perform'd, either by magnetiſm or tranſplantation. Nor is it only by the vulgar that ſuch cures are thought poſſible, for I find

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find them uſed and recommended by many eminent phyſicians. I know not what to think of the ſympathetic powder; but a very honeſt gentleman, well known to the learned world, by his writings, complaining to me of an ulcer in his bladder, which was continually exaſperated by the ſharp medicines he took, in hopes to diſſolve a ſtone in that part; I adviſed him to try this powder upon ſome of the matter voided with his urine, ſince no danger cou'd attend it. Soon after this, I had thanks for my advice, both from himſelf and his phyſician; for he was eaſed of the pain of his ulcer, and ſo continued for above a year; how much longer I know not. But I lay no ſtreſs upon this, nor the teſtimonies and relations of *Paracelſus*, *Helmont*, *Goclenius*, *Servius*, &c. who profeſſedly write in defence of the weapon-ſalve; upon account of ſome trials I myſelf have made, both upon that, and the ſympathetic powder; tho' I cannot but ſay, I have ſometimes found them available; and ſeen ſomething follow upon the uſe of the latter that inclined me to think it might, ſometimes, perform cures. But to produce leſs exceptionable authorities, *Dominicus Panarola* tells us, "wonders are, every "day, diſcover'd in phyſic; which confirm what *Servius* delivers of the weapon-"ſalve: that the menſes are ſtopp'd by a rag dipp'd in the matter excreted, and "placed under hot aſhes, has been frequently experienced; and *Caſtellus* declared "he had found, that if the hemorrhoids were touched with the bulbous root of "chondrilla, they dried away, if the roots were dried, but rotted if that rotted; "for which reaſon, after being thus uſed, it was put to wither in a chimney." The learned *Salmuth* gives us an example of a violent pain, in the arm, removed by tranſplantation. The way was this: red coral beat up with oaken leaves, were kept to the part affected till ſuppuration; then, in the morning, this mixture was put into a hole, bor'd with an auger, into the root of an oak, on the eaſt ſide thereof, the hole being ſtopped up with a peg, made of the ſame tree; and from that time, the pain entirely ceaſed; but upon taking out the amulet, it return'd ſharper than before. A great lady, far from being credulous, confeſs'd to me, as did alſo ſome of her ſervants, that, with the common remedy of aſh aſhes, form'd by warm urine, into ſeven or nine cakes, and buried for ſome days in a dunghill, ſhe was cured of the yellow-jaundice, after paſſing through a tedious courſe of phyſic, in vain preſcribed her for it, by the moſt famous phyſician in *England*; and afterwards, relapſing into the ſame diſeaſe, it was again removed by the ſame means. A phyſician, alſo, told me, that having been long afflicted with an obſtinate maraſmus, which prevailed upon him in ſpite of all the remedies he could uſe; at length, he reſolved to try a ſympathetic, which I have found in *Hartman*. He boiled an egg, till 'twas hard, in his own warm urine, and with a bodkin perforating the ſhell, in many places, he buried it in an ant-hill, where, as the emmets devoured it, he found his diſtemper leſſen, and his ſtrength encreaſe; ſo that at the time he related this, he thought himſelf well. *Riverius* tells us, that the daughter of a great officer in *France* was exceſſively tormented with a whitlow, for four days together; for which he order'd her finger to be put into a cat's ear; and, within two hours after, ſhe was freed from her pain, and the whole hand, which was tumified, came to its natural ſize, except the finger. The ſame author relates, that a counſellor's wife, after being four days tormented with the like, was cured by the ſame remedy, within a quarter of an hour.

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hour. 'Twas remarkable, that, in both theſe caſes, the cats gave ſuch manifeſt ſigns of pain, that *Riverius* thought they attracted the morbific matter of the patients. But *Peter Borelli* declares, that even the pain of the gout is greatly eaſed by admitting whelps to lie in the ſame bed, with the perſon afflicted; and affirms, they thereby contract the diſtemper, ſo far as to go lame. Perhaps, this author was induced to write thus from the report, that *Fludd*, the chymiſt, had by this means tranſplanted the gout from one of his patients; the dog being afterwards ſubject to ſuch periodical fits, as formerly afflicted his maſter.

Diſcourſing upon this ſubject, lately, with a judicious perſon, well ſkill'd in phyſic, and made eminent by his learned writings, he acquainted me with a cure, by tranſplantation, perform'd on the ſon of one who uſed to make chymical veſſels for me. The obſervation being conſiderable, and to avoid miſtakes, I deſired it in writing, which he gave me as follows. "*N. N.* of *N.* Potter, had "a ſon, who was long ſick of the king's-evil, which ſwell'd much, and broke "into ſores at laſt, which he could by no ordinary means heal. The old man "had then a dog, which took an uſe of licking the ſores; which the dog con-"tinued ſo long, that he waſted the very kernels of ulcers that were knit in with "the veins, and perfectly cured the ſore; but had the ſwelling tranſplanted to "himſelf, ſo that he had, thereupon, a great ſwelling, that aroſe and continued "in his throat. The lad was thereby freed, ſo continued to be till 1660, and, "for aught I know, is ſo to this day. This I ſaw, being there at that time, to "view the clayes and beſpeak retorts of the old man."

And *Bartholin* relates, that a dog, having relieved his uncle from the colic, by being placed upon his belly, afterwards vomited violently. He adds, that a ſervant of the ſame perſon, having the tooth-ach, found eaſe by applying the ſame dog to her cheeks, whilſt he diſcover'd manifeſt ſigns of pain; and, alſo, that the ſecretary found the like ſucceſs, in a ſwell'd neck. Nay, Sir *Francis Bacon*, himſelf, ſolemnly records the manner how he was freed from a great number of warts, by a piece of lard with the ſkin on, which, after having rubbed upon them, he expoſed, out of a ſouth window, to putrefy. And, therefore, tho' the vanity and ſuperſtition of thoſe who treat of magnetic remedies, together with the impertinent circumſtances uſually preſcribed, along with them, do uſually, with juſtice, render them ſuſpected by ſober men; yet by the inſtances here produced, whereto others might, alſo, be added, join'd to the teſtimonies of phyſicians, and others, who either perform'd, or were eye-witneſſes of ſuch cures, it ſeems proper, that farther experiments of this kind, ſhould be rigorouſly made. I cannot but commend the curioſity of Dr. *Harvey*, who did not ſcruple to try frequently the experiment, mention'd by *Helmont*, of holding the hand of a man, dead of a lingering diſeaſe, upon tumours or excreſcences, in order to cure them; which, the Doctor told me, he had, ſometimes, found inſignificant, but often effectual. Nor, if a ſingle experiment, of this kind, fails, does it follow, that it ought to be totally rejected; becauſe, if they ſometimes ſucceed, that ſufficiently ſhews there are medicines in nature, which operate after that extraordinary manner. And why ſhould we expect that remedies, which operate, at a diſtance, or only by their effluvia, muſt be more infallible than thoſe taken in at the mouth? If rhubarb be an excellent medicine in diarrhœas, notwithſtanding the uſe whereof, vaſt numbers are daily ſwept away

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way in *Ireland* by that diſtemper; if mercury be effectual in venereal caſes, tho', according to *Fernelius*, *Montanus*, and others, it ſeldom cures them; and, laſtly, *if* diaphoretics are juſtly eſteem'd by phyſicians, tho' few, if any of them, *will* cauſe ſweat in all bodies; why may not remedies, which operate, as it were, by emanation, deſerve the names of medicines, if they, ſometimes, unqueſtionably ſucceed, and be try'd as ſuch, when they are ſo exceeding ſafe and innocent?

To make medicinal experiments upon brutes, recommended.

But it may here be demanded, how a naturaliſt can contribute to advance theſe methods of cure, without evacuations? I anſwer, 'tis no new thing for naturaliſts, who are no profeſs'd phyſicians, to treat of this ſubject; and that they may afford good hints to one who is; not only, by the ways already mention'd, but, alſo, by trying, upon brutes, variety of unexperienc'd medicines, and communicating the ſucceſs thereof. *Periculum faciendum eſt in vili animâ*; we may, therefore, inflict wounds upon dogs and monkeys, and give them poiſons, purpoſely to try the efficacy of the weapon-ſalve, and ſympathy-powder. And ſome of my friends aſſure me, they have cur'd lame horſes, by ſticking the nails, that did the hurt, into the weapon-ſalve; which they carry about them, for that purpoſe. When cattle are afflicted with the turning-evil, or ſturdy; a diſeaſe that cauſes them to turn, frequently, round in the ſame place; the common remedy in *England*, is to throw the beaſt down and bind him; then to open his ſkull, and take out a little bladder, which, uſually, lies near the membranes of the brain, fill'd with water and blood; and then gradually heal up the wound. And this method is much commended by our experienced *Markham*. In goats, likewiſe, which are ſubject to the dropſy, the huſband-men make a ſlit under the ſhoulder, and let out the water. Various other hazardous operations in chirurgery, as arteriotomy, the extirpation of the ſpleen, *&c.* either were, or ought to have been, firſt practiſed upon brutes; and by proceeding, in this manner, 'tis probable, that many uſeful diſcoveries may be made in chirurgery. To paſs by the known practice of ſpaying ſwine and bitches; ſome experienc'd ſhepherds have a particular way of caſtrating male ſheep, eſpecially when grown ſo old, that the common method is unſafe. The operation is call'd ſwigging; and they perform it by throwing the creature on his back; in which poſture he is held by a ſtrong man, while another draws a ſtring, as tight as poſſible, about the teſticles; and fixing it there, they anoint the part with freſh butter, and leave the ram to feed; and in two or three days the teſticles grow ſo rotten, as to fall of with the ſtring, or to be pluck'd away by a ſmall force.

From the practice of farriers, ſhepherds, and graziers, many things may be drawn to enrich, or illuſtrate, the method of cure in human bodies; for their ignorance and credulity, with the meanneſs of the creatures they practiſe upon, lead them, to venture, in horſes and cattle, what phyſicians dare not upon men and women. Some of theſe extravagant experiments have, however, ſucceeded ſo well, as to deſerve the conſideration of the moſt ſkilful phyſicians. And, methinks, ſome of them might without any diſgrace to their profeſſion, oblige the world by collecting and digeſting all the approv'd experience of farriers, graziers, butchers, and the like. The ancients did not deſpiſe ſuch an employment, but honour'd it with the titles *Hippiatrica* and *Veterinaria*. To give one example of the

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the ſervice this might do to the art of healing, I chuſe to inſtance in the cure of the ſtaggers in horſes, by bleeding. I have ſeen a coach-horſe ready to drop down dead, of this diſeaſe, on the road; but upon well rubbing his gums, with the coach-whip, till they bled, he was inſtantly relieved, and enabled to perform his journey.

We muſt next obſerve, that phyſic anciently belong'd to the naturaliſt, according to that remarkable paſſage of *Celſus*, "phyſic," ſays he, "was originally "eſteem'd a part of philoſophy; and the cure of diſeaſes grew up with the ſtudy "of nature: indeed, the naturaliſts ſtood moſt in need of it, who exhauſted "their vigour in lucubrations." He adds, that many philoſophers were, alſo, phyſicians; and that *Hippocrates* was the firſt who made a diſtinction between them. And this we ſuppoſe a ſufficient apology for the preſent diſcourſe.

Reaſons for the uſe of ſpecifics. Now the reaſon why phyſicians reject, or deride the uſe of ſpecifics, being becauſe they ſeem to operate in a ſecret and unknown manner, and not by viſibly evacuating the peccant matter; and a naturaliſt may remove this objection, by ſhewing, that there are ſimilar effects in nature; and, conſequently, that theſe ought not to be rejected as impoſſible. 'Tis certain, that the ſchool-philoſophy does great diſſervice to phyſicians, by leading them into groſs conceptions of nature's manner of working; and hence it is, that many learned men, among them, never expect any great effects from remedies that fall not under the ſenſes, nor evacuate any ſenſible matter; whereas very great alterations may be wrought in a body, eſpecially, if fluid, by the inteſtine motion, alone, of the parts. How much an imperceptible avolation of a few ſubtile parts of a liquor can alter its nature, we may gueſs by the obvious change of wine into vinegar. In *England*, indeed, by reaſon of the coldneſs of the climate, this degeneration is not ſo ſudden as in hotter countries: but in *Brazil*, *Piſo* informs us, that the expreſs'd juice of the ſugar-cane, which, by coction, would ſoon be brought to ſugar, will, of itſelf, keep ſweet but four and twenty hours, when it begins to grow ſour, and become unfit for that purpoſe, but proper for vinegar. The ſame thing is, alſo, confirmed, by travellers, of ſome other liquors in the *Weſt-Indies*. But *Linſchoten* tells us of a much more ſudden change in the *Eaſt-Indies*. "The ſura, or juice of the coco-tree," ſays he, "if it ſtands but "an hour in the Sun, becomes very good vinegar, and the *Indians* uſe no other." That noxious liquors, (and why not peccant matter in the body?) in like manner, change their nature, appears from what we formerly obſerved of the juice of mandihoca; which, tho' poiſonous when firſt expreſs'd, purges itſelf, in a few hours, and becomes wholeſome. That the bare admiſſion of ſome ſubtile and inviſible matter, may raiſe ſuch inteſtine commotions in fluids, appears from the frequent ſouring or ſpoiling of liquors by thunder: and, at *Geneva*, I remember, the inhabitants complain'd, that much of their wine was turned ſour by an earth-quake.

That ſuch inviſible corpuſcles, may fly from amulets, or other external remedies into the blood and juices; and there produce conſiderable changes, will not appear ſtrange to him who conſiders, according to *Hippocrates*, how perſpirable a living body is; and that vegetable and animal ſubſtances may well have ſuch exhalations, ſince, even, minerals are not without them. Sulphur, and amber

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ber are made, by friction, to omit odorable steams; glass of antimony, and *Crocus metallorum*, impart an emetic quality to fluids, without sensibly losing of their bulk and weight; and quick-silver, in the same manner, communicates the virtue of destroying worms, to wine or water, by being only shook with them. I have wonder'd how, many learned physicians, among the moderns, either out of an affected severity, or, perhaps, animosity, against the chymists, could express a contempt of all operations of this nature; since *Galen* himself, not only confirms, the like doctrine by his reasons and authority, but delivers a surprizing example thereof, in piony-root; which he, by repeated experiments, satisfied himself, cured a lad of an epilepsy, by being hung about his neck; for the distemper return'd if this were taken off. And this effect he accounts for from the effluvia of the root. Nay, to me it seems not impossible, that invisible bodies, by passing thro' more gross ones, should so far change the motion, or arrangement of their parts, as to produce lasting alterations in their textures; for the fluid body of quick-silver has, sometimes, without any sensible increase of bulk, been so coagulated by a metalline exhalation, that it might be cut like lead; and this solidity it will retain, 'till it be, by some art, reduced to its pristine fluidity. One might be induced to think, that iron has a permanent alteration made in it's texture, by holding a needle, long, near the pole of a vigorous load-stone; whereby the magnetic effluvia will so dispose the parts of the nearest extremity, as to admit the steams which come from one of the poles of the stone; whilst, by holding it to the contrary pole of the same, the texture of the needle will, presently, be quite otherwise disposed: and, by changing the poles of the load-stone, we have made it appear, that such alterations are possible in stones. Iron may, by different management after 'tis heated, be render'd either soft or brittle: and 'tis observed, that glass acquires a more, or less brittle texture, according as it is baked; for if glasses are carried into the open air, immediately after they are blown, and not set to cool, gradually, in an oven, they become brittle, and very apt to break: and whatever be the cause of this, 'tis evidently no gross, or visible matter.

That in a human body, likewise, great changes may be made by very subtile effluvia, appears from other things, as well as external remedies. Thus some are purged by the bare scent of a potion; as the physician of *Plymouth* assured me from his own observation: and *Salmuth* gives us an instance, where one, in this manner, operated better upon a young gentlewoman, than it did upon her sister who took it. The same author says, that Dr. *Pfeil*, when he wanted a purge, would go into the apothecary's shop, where purging electuaries were preparing, the scent whereof would work as well with him, as a dose of the medicine*. *Henricus ab Heer* tells us of a woman who used to purge herself with beef-broth; but, having broke her leg, used no other cathartic than the scent of it. *Josephus Acosta* relates, that the air, along the ridge of the

* M. *Lemery* says, he was acquainted with two persons, who, staying four or five hours, in a hot season, where there was a large quantity of damask-roses, they were purged thereby, in a most violent manner, both upwards and downwards. *Hist. de l'Academ. A.* 1695. p. 69.

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high mountain *Pariacaca*, in *Peru*, has, for five hundred leagues, ſuch ſtrange effects, that, tho' he went well prepared to withſtand it, yet, approaching the top, he was thrown into exceſſive retching and vomiting, even, 'till he caſt up blood. It, likewiſe, operated, downwards, with ſome of his companions; and he continued, thus, ſick for three or four hours, 'till he came into a more temperate air. A ſtill greater proof of the power that effluvia have upon the body, ariſes from the propagation of infectious diſeaſes. Nor is it a wonder, that ſuch inſenſible particles ſhould have ſuch terrible effects upon our bodies, if we conſider what alterations may, therein, be produced from the action of the parts upon one another. Several paſſions of the mind are often excited by the bare thoughts of abſent things. In obſtinate grief and melancholy, there is ſuch an alteration made in the heart, and, perhaps, ſome other parts, thro' which the blood circulates, that the motion of that fluid is diſturbed; and obſtructions, and other diſorders, occaſion'd. The remembrance of a loathſome potion will, often produce a horror, attended with a ſenſible commotion of the whole body, and a kind of convulſion about the ſtomach. Shame, we ſee, occaſions the blood to be plentifully thrown into the face; as will, alſo, great and ſudden joy. I lately ſaw the latter paſſion do it, in perſons of both ſexes; when, not only their cheeks and fore-heads, but, even the neck and ſhoulders of the lady were left died of a red colour. Nay, paſſions, not only alter the motion of the fluids in the body; but, even, occaſion the evacuation of ſome of them. Thus grief forces tears. And longing, in women, may well be ſuppoſed to create great alterations in the body of the mother, when it will leave ſuch ſtrange and laſting impreſſions upon that of the infant; ſince it is her, alone, that has ſuch importunate deſires.

Diſeaſes from imagination.

There are many inſtances, in phyſic books, to ſhew, that imagination may cauſe a diſeaſe, where it is exceſſively fear'd; and I myſelf knew a lady who had the ſmall-pox by this means. Nor is it, only, in women, that conceit has theſe effects. There was an *Iriſh* captain, in the county of *Cork*, of a middle age; who coming to ſurrender himſelf to my brother *Broghill*, at that time commander of the *Engliſh* forces there, was intercepted by a party of *Engliſh*. My brother being abſent, the captain was ſo fearful of being put to death, before he return'd, that it ſoon alter'd the colour of his hair. Happening to be then at the caſtle, whereto this captain was brought, I found, upon examination, that the change of his hair was not uniform; but that particular tufts and locks thereof, with baſes about an inch in diameter, were, up and down, ſuddenly turn'd white, all over, whilſt the reſt remain'd of its own reddiſh colour.

But I muſt not be underſtood to condemn the uſe of evacuating medicines, or be thought ſo credulous as to believe all the virtues aſcribed, even by eminent writers, to ſpecifics; for I have obſerv'd the beſt of theſe remedies to fail, where an emetic, or cathartic has not preceded; unleſs they were of ſo abſterſive a nature, as, of themſelves, to free the firſt paſſages of thoſe viſcid humours that uſually lodge therein, and hinder their efficacy. My deſign is to prevent the prejudice propagated by ſome learned, but confident phyſicians, who laugh at the mention of ſpecifics, and allow no cures performable, without viſibly evacuating the peccant matter; and, alſo, to ſhew, that ſuch of theſe remedies, as men of judgment and credit recommend upon their own experience, are

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are not, without trial, to be rejected, becauſe they occaſion no ſenſible evacuation, nor, manifeſtly, diſcover any eminent quality, nor, laſtly, produce any remarkable change in an healthful body. For an animated human body is not a rude maſs of limbs and liquors, but an engine conſiſting of ſeveral parts, harmoniouſly connected together, and communicating with each other; by means whereof, a weak impreſſion of adventitious matter, in one part, ſhall act upon another, at a diſtance, or even, upon the whole machine. The ſlight motion of a man's finger upon a ſmall piece of iron, unconnected with any engine, would produce no conſiderable effect; but ſuch an action, applied to the trigger of a loaded muſket, occaſions a ſurprizing ſucceſſion of accidents. That a human body is ſo framed, as to ſuffer great changes from ſeemingly gentle impreſſions of external objects, appears from many inſtances already mention'd. Thus, likewiſe, to go, ſuddenly, into the ſun-ſhine, will, ſometimes, inſtantly occaſion that violent motion we call ſneezing. To look from a precipice, will make the head giddy; the ſight of a whirl-pool has cauſed men to fall into it; and to fix the eyes upon the water, beneath a ſhip under ſail, will prove emetic; as I, for my health's ſake, have, ſometimes, experienced. If a perſon be tickliſh, ſtroke the ſole of his foot with a feather, and it ſhall, againſt his will, affect the remote muſcles of his face, and provoke him to laughter; as the tickling of a ſtraw in the noſtrils, excites ſneezing. Many kinds of a grating noiſe will ſet the teeth on edge; and a ſervant of mine complain'd, that the whetting a knife would make his gums bleed. *Henricus ab Heer* mentions a lady who would faint at the ſound of a bell, or any loud noiſe, even that of ſinging, and lye as if ſhe were dead; but as ſhe was thoroughly cured by a courſe of phyſic, it appears, that this diſpoſition proceeded from ſome particular texture in her body, with regard to ſounds. One hyſterical woman, in fits, ſhall ſoon communicate them to another by aſpect. And, to ſhew that diſtemper'd bodies may receive alterations, while ſound ones remain the ſame; we need, only, conſider, that the ſubtile effluvia, which float in the air, before any change of weather, are felt by thoſe valetudinarians, who have, formerly receiv'd bruiſes, wounds, or other injuries; and that too, only, in the very parts where they happen'd. Others, we daily ſee, who are diſorder'd by riding backwards in a coach; and the ſcent of muſk, or amber-greaſe, tho' grateful to others, will throw hyſterical women into ſtrange convulſions. *Zacutus Luſitanus* tells us of a fiſher-man, who, having ſpent his life at ſea, and coming, accidentally, to the reception of the king of *Portugal*, in a maritime town, where perfumes were burnt; he was, thereby thrown into a fit, judged apoplectic by two phyſicians, who treated him accordingly; 'till three days after, the king's phyſician, gueſſing the cauſe, order'd him to be remov'd to the ſea-ſide, and there to be cover'd with ſea-weed, which ſoon recover'd him.

The human body a machine, and acted upon accordingly.

How much an alteration, produced in the body by ſickneſs, may diſpoſe it to receive impreſſions from what would not, otherwiſe, much affect it, may be gueſs'd from the effects of cold liquors thereon, when it is only heated: a man, in perfect health, who uſually drinks his liquors cold, may, at that time, by a draught of cold water, or beer, be ſuddenly caſt into ſuch dangerous diſtem-

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pers, as, did not daily experience convince us, we ſhou'd think impoſſible to be, thereby, occaſion'd, in a body free from morbid humours. *Benivenius* informs us of one, who, after vehement exerciſe, drinking a glaſs of very cold water, immediately, fell into a ſwound and died: yet in bodies otherwiſe diſpoſed, cold water has, ſometimes, very good effects; and I know ſome hyſterical ladies who find it an excellent remedy.

But the body is, alſo, as eaſily alterable for the better. The true moſs of a human ſkull, tho' experience will not countenance all that the chymiſts ſay of it, proves ſometimes a wonderful ſtyptic. An eminent virtuoſo, with whom I am well acquainted, as alſo his phyſician, aſſured me, he finds the effects of this moſs ſo great upon himſelf, that his arm bleeding again, when tied up after phlebotomy, he took a little of it into his hand, and the blood immediately ceaſed to flow; he, thrice, for experiment's ſake, laid aſide the moſs, when, his arm began to bleed again; but upon refuming thereof, it, each time, preſently, ſtopp'd. The fume of burnt feathers, or tobacco, blown into the face of hyſterical women, as ſuddenly relieves them from their fits, as perfumes occaſion them. A friend of mine, a perſon of great veracity, profeſſes, he has cured dyſenteries, by fumigating the anus, and parts adjacent, with ginger, thrown upon hot embers, and receiv'd in a convenient poſture, as long as poſſible, without too great faintneſs: but a maſter of chymical ſecrets prefers for this purpoſe hart's-horn ſhavings. But if the heat, in this caſe, contributes to the effect, we may reaſonably ſuppoſe, that cures are performable by particles more minute than thoſe of ſmoke. And, indeed, I know a dextrous goldſmith, who, when he over-heats himſelf, is ſubject to the gripes; which he, uſually, remedies by ſitting, for ſome time, upon a heated anvil. Some find more relief in the colic from the ſmoke of tobacco receiv'd glyſter-wiſe, than by any other phyſic; and, to my knowledge, ſome wealthy perſons, relying hereon, never employ a phyſician for this diſtemper. And conſidering what a ſubſtance even common ſoot is, that many things, by being reſolved into ſmoke, are more open'd than they wou'd be in the ſtomach; that, by this means, the operations of the many emetic and cathartic ſimples may be heighten'd; and that, probably, ſome fumes and odours are more powerful for not paſſing thro' the mouth; theſe things conſider'd, I ſay, incline me to think ſome farther uſe might be made hereof. Not to mention, again, the great virtues of ſuphureous ſmoke to preſerve liquors; and that both *Paracelſus* and *Helmont*, highly extol, as a ſpecific, the warts that grow on horſes legs, againſt the fits of the mother; I lately met with a curious and intelligent perſon, who aſſured me, he was, by the ſcurvy and obſtinate ulcers, brought exceeding low, and having, in vain, upon that account, undergone ſeveral tedious courſes of phyſic, he reſolved againſt them for the future; but lighting on a chirurgeon who had perform'd many extraordinary cures, by a method no way troubleſome, he ſubmitted thereto, and was ſoon cured. His method was to fumigate the patient very well, every morning, with a powder that appear'd of a vegetable ſubſtance. But as to the efficacy of fumes; I have, more than once, recover'd a young lady from ſtrange fits, that we judg'd epileptic, by the ſcent of a little vial fill'd with rectified ſpirit of ſal-armoniac, or hart's-horn. And another lady, who, tho' ſhe has long been ſubject to violent and laſting fits of the head-ach, which was, greatly,

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increaſed by a violent concuſſion, from the overturning of a coach; yet finds preſent relief by holding her head over a ſtrong decoction of tea, and breathing the ſteams thereof. But there's one thing that ſeems, by no means, ſufficiently attended to, in *Europe*; I mean, the conſtant and ſudden ceaſing of the plague, how violent ſoever, in that vaſtly populous city *Grand Cairo*, towards the latter end of *June*; when, in our hemiſphere, it, uſually, ſpreads the faſteſt. The truth of this is atteſted by travellers of different nations, as well as *Proſper Alpinus*, an excellent phyſician, who ſpent many years in that country, and gives this account of the matter. "The plague," ſays he, "begins in *Cairo*, "and all the parts of *Egypt*, with *September*, and continues till *June*; in all the "intermediate months 'tis communicated to them, by contagion, from abroad: "but in the month of *June*, let the diſtemper there, rage ever ſo ſeverely, as ſoon "as ever the ſun enters *Cancer*, it, perfectly, ceaſes; and what is very ſur-"priſing, all manner of goods that were infected thereby, become innocent "thro' the whole nation, and every thing grows calm and well; only ſpora-"dic diſeaſes, then, ſpring up, which no where appear while the plague rages." And this ſtrange effect he wholly attributes to an alteration in the air. I deſire this inſtance may be the more particularly conſider'd, becauſe it greatly confirms and illuſtrates what we have already ſaid concerning the poſſibility of nature's curing diſeaſes, without the help of groſs and ſenſible evacuations.

We may farther obſerve, that the human body is alterable, both for the better and worſe, by groſs or mere mechanical motions. Perſons are, often, recover'd from fits or ſwounding by bare pinching. I, who have gone thro' great and dangerous fits of ſickneſs, ſcarce ever found any more violent, for the time, than that occaſion'd by the motion and ſcent of a ſhip, together with the air at ſea, before I was uſed to navigation; and yet this violent illneſs, as it was cauſed by no peccant humour in the body, was quickly removed by a quiet ſhore and change of air: and the like is, ſometimes, obſervable upon riding in a coach; which is ſoon reliev'd by a ceſſation of the motion thereof. We ſee, in our ſtables, what effect the curry-comb has upon horſes. *Helmont* ſays, he could tell, by the taſte of the milk, whether the aſs that gave it had been curried that day: but ſuch an alteration ſeems to argue a greater in the blood and other principal parts of the body. *Piſo* informs us, that the illiterate *Brazilian* empirics perform ſurprizing things both in the preſervation of health, and the cure of many diſeaſes, by their frictions in chronical, and unguents in acute caſes. And as *Galen* commends a proper application of cupping-glaſſes in the colic; ſo in *Brazil* they find them very ſucceſsful therein; being chiefly fixed, according to *Piſo*, on the region of the liver. The horrid ſymptoms conſequent upon the bite of a *Tarantula*, give way to nothing ſo well as muſic, which, by ſome means or other, cauſes the patient to leap, dance, and ſweat, till he breathes out the virulent matter, that ſeems fitted for expulſion, thro' a change wrought either upon this, or the blood, by the muſic; for ſudorifics and exercife, without muſic, are ſo far from effecting the cure, that, as *Kircher* informs us, the magiſtrates of *Apulia* allow public ſalaries for muſicians, who play to the poor upon this occaſion. The ſame author gives us a remarkable ſtory of a nobleman, who languiſhing under a diſtemper, not ſuſpected to proceed from the bite of a *Tarantula*, 'till he ſeem'd near

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near the point of death, was, at length, ſuddenly reliev'd, and gradually recover'd, by muſic. And *Epiphanius Ferdinandus*, *Mathiolus*, and others, have the like relations. Now, that a ſound may powerfully operate upon the blood and ſpirits, I my ſelf, who delight in muſic, have often obſerved, upon hearing certain notes. This, alſo, ſeems probable, from the effect which, as we formerly ſaid, a grating noiſe has upon the teeth and gums; and by the dancing fit in the preſent caſe, whereto it is only a particular tune that excites. Nay, *Kircher* farther affirms, that the *Tarantulæ* themſelves, as well as the *Tarantati*, may be made to dance, by tunes ſuited to their conſtitutions. *Epiphanius Ferdinandus*, alſo, agrees herein, and tells us of a man ninety four years old, and render'd ſo weak, that he cou'd hardly walk with the help of a ſtaff, who, being bitten by a *Tarantula*, immediately, at the ſound of muſic, fell to dancing and capering like a kid. He adds, that not only men, in whom much may be attributed to fancy, but other animals do the ſame; and inſtances in a waſp, which he ſaw dance to muſic, together with the *Tarantula* that bit him; and alſo in a cock.

Peculiarities of conſtitutions. But, moreover, there are many ſtrange peculiarities in ſome perſons, both in ſickneſs and in health. Theſe differences, indeed, between healthy men, may not be greater than that obſervable in the ſame perſon, between a ſound and a diſtemper'd ſtate; yet we, frequently, ſee, that ſome bodies are ſo framed, as to be ſtrangely diſorder'd by ſuch things as either not at all, or elſe differently affect thoſe of others. Thus, 'tis common for men to expreſs great uneaſineſs, and fall into fits of trembling, at the ſight of a cat. This was the caſe of the late gallant and noble Earl of *Barrymore*, who had the like averſion to tanſey. And I my ſelf cannot behold a ſpider near me, without a great commotion in my blood; tho' I never receiv'd any hurt from that creature, and have no abhorrence of toads, vipers, or other venomous animals. I alſo know an excellent lady, who is remarkable for a ſtrange antipathy to honey. Her phyſician ſuppoſing this, in ſome meaſure, imaginary, mixed a little honey in a remedy he applied to a very ſlight ſcratch, ſhe happen'd to receive on her foot; but he ſoon repented of his curioſity, for it cauſed a ſtrange and unexpected diſorder, which ceaſed upon the removal of that medicine, and the application of others. The ſame excellent perſon complain'd to me, that the vulgar pectoral remedies did her no ſervice in coughs, wherewith ſhe was troubled, and which nothing reliev'd but either the fume of amber, receiv'd by a pipe, with that of proper herbs, or, the balſam of ſulphur. I know an ingenious gentlewoman, on whom cinnamon, which, generally, is, conſiderably aſtringent and ſtomachic, has a quite contrary effect, and this in a ſtrange degree, ſo that having found by two or three accidental trials, that a very little cinnamon ſeem'd to diſorder her ſtomach, and prove laxative; ſhe, once, reſolved to ſatisfy her ſelf, whether theſe diſcompoſures came by chance or no; and having ſtrew'd ſome powder'd cinnamon upon a toaſt, ſhe eat it, and was thereby purged, for two days together, with ſuch violence, that it cauſed convulſions, and a ſpaſmus, which ſhe continues to be troubled with, from time to time, tho' 'tis three years ſince ſhe made the experiment; as was averr'd to me by her husband, a phyſician *. A perſon of quality lately

* On the other hand, *M. Lemery* tells us, he knew a chymiſt, who cou'd eat *Mercurius dulcis* as if it were bread; and that he has ſeen him chew and ſwallow down four ounces at once, without any ſenſible effect. *Hiſt. de l'Academ.* A. 1699. p. 69.

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aſked me, whether he ſhou'd continue the uſe of coffee as an emetic; becauſe he had found it operate very violently with him. Inquiring, particularly, into this odd effect, I found, that an ordinary wine-glaſs full of the common liquor, coffee, wou'd, in two hours time, vomit him more ſeverely than the infuſion of *Crocus metallorum*, or other uſual emetics; that this had been, for ſeveral years, his conſtant vomit; that ſcarce any one was more irkſome, than this, of late, grew, to take; ſo that the ſcent of a coffee-houſe wou'd make him ſick; and, laſtly, that he himſelf had formerly uſed it long together for the fumes which offended his head, without obſerving any emetic quality therein. The writings of ſober phyſicians afford us many other ſtrange inſtances of this peculiarity of conſtitutions; and of ſuch as have deſired to eat very extravagant and abſurd things, which, tho' they, ſometimes, were directly contrary to their diſtempers, have perform'd cures in deſperate caſes. And this appears the more probable from what we frequently ſee done by longing women, and virgins in the green-ſickneſs. But now, if a human body be ſo framed, as to receive alterations from ſuch unlikely things as theſe, why ſhou'd ſpecifics be haſtily condemn'd, which, tho' they operate inſenſibly, come recommended by the experience of ſober and credible perſons? That an inconſiderable quantity of matter, once admitted into the body, may give a new and unnatural determination to the motion of the blood, an alteration to the texture, either of that, or of ſome noble part, and as a little leaven, ferment the whole lump, appears from the effects of poiſons, which are not produced by thoſe the phyſicians call manifeſt qualities. Moſt writers upon poiſons, indeed, ſuppoſing men wou'd rather believe than repeat their experiments, have deliver'd many things more ſtrange than true; yet the known effects of a little opium, or arſenic, the ſcarce diſcernible virus emitted by the viper, and the ſmall quantity of the ſaliva of a mad dog, leſs than half a grain whereof will deſtroy an ox, abundantly illuſtrate and confirm all we have deliver'd, upon the head of ſpecifics. And that a morbid body may be, ſometimes, cured with as ſmall a matter as wou'd diſorder a ſound one, is manifeſt from that experiment, common in *Italy* and elſewhere, of curing the venomous bite of a ſcorpion, by anointing the tumid part with common oil, wherein live ſcorpions have been ſteep'd. *Piſo* tells us, that he ſaw an huge over-grown toad, ſwell'd with poiſon, and deſperately venomous, that was preſently kill'd, by a *Brazilian*, only with dropping on his back, the juice of the plant *Nhanby*. He farther declares, that an infuſion of the root *Joborandi* reſcu'd, to his knowledge, many from imminent death, who had eaten ſeveral ſorts of poiſon; and this, after the whole tribe of *European* alexipharmics had proved unſucceſsful. It may here be objected, that my inſtances only reach to poiſons, and their antidotes, not to diſeaſes, and their ſpecifics. I anſwer, firſt, that phyſicians treat theſe as diſtempers, and that they, really, are ſo; but heighten'd by a virulent malignity, which is not eaſily diſtinguiſhable from them; as appears by the frequent diſputes of phyſicians, whether or no their patients died of poiſon. Some of the *Brazilians*, indeed, according to *Piſo*, are ſo dextrous in mixing their poiſons, as to prevent the pernicious effects thereof, for a long time, after they are taken: but then, their quantity is ſo ſmall, in compariſon of the morbific matter of ſurfeits, or other ſimilar diſeaſes, their ſymptoms ſo dreadful,

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and conſequences ſo deſtructive, that the cure hereof beſt ſerves to ſhew how powerfully nature may be aſſiſted by remedies, whoſe operation is inſenſible. Secondly, there are many paſſages in the preceding diſcourſe, as, particularly, where mention is made of the cure of agues, the rickets, and the king's-evil, which ſhew, that common diſeaſes, alſo, are curable by ſpecifics.

New remedies to be uſed where the old ones have failed.

But ſuppoſe, ſay you, a recommended ſpecific ſhou'd appear not only unable to cure, but likely to augment the diſeaſe? Why then, we muſt conſider, 'tis better for the patient to be cured by raſh and imprudent means, than be ſuffer'd to die according to art; and that the phyſician, who loſes his patient, after having long ſtruggled to ſave him, deſerves more commendation than he who ſhou'd chance to cure one by an irrational method. The phyſician ought, therefore, to be well ſatisfied of the ground he goes on, before he ventures upon ſuch a remedy, eſpecially, if he has not tried the more ordinary and unſuſpected means, and found them ineffectual; for 'tis not one lucky cure that will recommend a remedy to a wary phyſician, when the dangerous quality thereof ſeems obvious, and its virtues are only known by report. But then, if a phyſician be well aſſured of the efficacy of ſuch a remedy, by a variety of trials, he may, ſurely, without raſhneſs, make uſe of it, at leaſt, where ordinary medicines have failed.

Many reaſons might be produced to enforce this practice. And, firſt, the true nature and cauſes of ſeveral diſeaſes, are more unknown to phyſicians, than is generally thought; nor is the particular method of cure, thereon depending, more ſettled among them. The generality of phyſicians, I fear, are guided by narrow ſcholaſtic principles, not by nature: nor have they, once, well enumerated and diſtinguiſh'd the ſeveral aſſignable cauſes for the phenomena of diſeaſes; or told us, by how many different ways they, and their ſymptoms, may be removed. If this were analytically and carefully done, I doubt not but men's knowledge in phyſic, would be more extenſive, and effectual, than it is at preſent; and we ſhould, then, find many probable and promiſing methods of cure, which are now overlook'd. A phyſician, indeed, is, in a due ſenſe, the ſervant of nature; yet, ſuch kind of expreſſions, I ſuſpect, has hinder'd the advancement of phyſic, by diverting the minds of men from thinking of thoſe methods, which, by powerfully altering the human machine, rectifying the motion and texture of it's parts, and accuſtoming it to proper courſes of the blood and juices, and time and methods of evacuation, might prevent, or cure ſome ſtubborn diſeaſes, more happily than the vulgar means. And, till men have a better knowledge in the principles of natural philoſophy, we muſt not expect a more perfect and comprehenſive theory of phyſic. That the preſent practice often proceeds upon a falſe foundation, might be ſhewn in abundance of inſtances; but I ſhall mention, at preſent, only the laſt I met with. An intimate acquaintance of mine, having been many months troubled with a difficulty of breathing, was unſucceſsfully treated for it, by ſome very eminent phyſicians; till, at length, ſuſpecting 'twas not the lungs, but the nerves of the adjacent parts, that were affected, our volatile ſalt was given, which, quickly, relieved him, and he was, afterwards convinced, that the lungs were not in fault.

As the common method, in ſhort, with the theories founded thereon, is, in many caſes, ſo diſputable, that the ſucceſs of a remedy ſeems to be more pro-

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bable, than the receiv'd notion of ſome diſeaſes; it were not amiſs, if we conſider'd the ſaying of the old empirics in *Celſus*. "We don't ſay, that a phyſi-"cian ſhou'd act, without reaſon; or, that an irrational creature can practiſe "phyſic: but that conjectural hypotheſes, about obſcure things, belong not to "it: for the queſtion is not, what cauſes, but what cures, a diſtemper." And, as the proper method is not agreed upon, in the ſchools; ſo many, who are perfect ſtrangers to them, by means of ſpecifics, their own experience, and common ſenſe, perform conſiderable cures. *Piſo* gives the following teſtimony of the utterly unlearn'd *Brazilian* empirics. "The more elderly, and expe-"rienc'd, among them," ſays he "are, excellently, ſkill'd in botany, and phar-"macy; by which means, they eaſily prepare all kinds of remedies from what "they find in the woods; and theſe they apply both externally, and internally, "but eſpecially in diſtempers occaſion'd by poiſon, with ſo great ſagacity, that "it is ſafer falling into their hands, than into the hands of our raw phyſicians, "who are, perpetually, boaſting of their education, and ſecrets."

A phyſician, who practiſed, with great ſucceſs, in *Dublin*, whilſt new and violent fevers raged there, whereof multitudes died, and very few recover'd; happily hit upon a method that proved very proſperous; whereof he gave me the following account by letter: which may, perhaps, afford good hints towards the cure of ſome other ill-condition'd fevers.

Dublin, Feb. 27. 1682.

"I Have employ'd *Ens Veneris*, for the removal of a *Subſultus Tendinum*, in "a perſon dangerouſly ſick of a *Febris Petechialis*, (a diſeaſe fatal to very "many, here, for theſe twelve or fourteen months;) and found that it anſwer'd "my hopes, in three or four hours after I gave it in conſerve of borage flowers.

"I have thought of a method of curing the aforeſaid fever, which has not "once fail'd me; tho' I made uſe of it for ſixteen or eighteen ſeveral perſons; "many of which, would, certainly, have died, if treated, after the uſual manner, "in this caſe. When firſt I come to any ſick of this diſeaſe, if I find them "coſtive, (as, generally, they are,) I preſcribe a glyſter, and, after that, a large "bliſtering plaiſter, between the ſhoulders; the bliſter being well rais'd, and "carefully dreſs'd, ſtripping off the cuticula, continues running till the fever is "gone off; which happens, moſt commonly, in ten or twelve days, if they have "not kept up too long with it; for then we cannot, certainly, foretel the time "of the fever's declination. For the whole time, till the going off of the fever, "I preſcribe emulſions of *Aq. Aronis. Card. Bened. Citrij totius, & Syr. Gra-"natorum, cum Aceto*; I allow of orange, and butter-milk poſſets, of roaſted "apples, flummery, or any other light, and cooling thing, they call for.

"By this method, I keep the *Genus Nervoſum*, and brain, from being af-"fected, and, conſequently, ſecure my patients; for, as many as I have ever "known of them die, in this diſeaſe, died of a diſorder of thoſe parts. I do "not defer the bliſtering plaiſters, till I find my patients delirious, lethargic, "convulſive, or otherwiſe affected in their heads, and nerves; finding, by the "experience of others, that, then, they, moſt commonly prove ineffectual, be-

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" cauſe of ſome morbific matter too deeply lodg'd in theſe parts. I do not pre-
" ſcribe, except upon ſome extraordinary occaſions, any volatile ſalts, or ſpirits,
" or any thing too apt to quicken the circulation of the blood, which is already
" too great; having, experimentally, learn'd, that by theſe, often us'd, the brain,
" and nerves, become, ſooner than ordinary, affected; for, they deeply inſi-
" nuate themſelves, and drive, with them, ſome morbific matter into the brain,
" and nerves. I find bleeding bad; being generally fatal. If I doubt of the re-
" covery of any of my patients, in this diſeaſe, 'tis, only, when I find they
" have been let blood, or lain for eight or nine days before I come to them;
" tho' I have recover'd even perſons in thoſe circumſtances."

Medicines, apparently oppoſite to a diſeaſe, may cure it.

Secondly, there are many medicines endow'd with a quality, apt to encreaſe the diſeaſe wherein they are preſcribed, whoſe uſe is yet approved of by the moſt judicious phyſicians, becauſe they poſſeſs others which produce ſuperior good effects. Thus, in a malignant fever, *Venice-treacle*, and other hot ſudorifics, are order'd; ſince they relieve the patient more, by ſome other means, than an encreaſe of heat, for a ſeaſon, can prejudice him. *Bontius*, for the ſpaſmus, which he reckons endemial in the *Eaſt-Indies*, commends the uſe of *Quercetan's Laudanum*, of *Philonium*, and, particularly, of an extract of opium, and ſaffron; and, to prevent any prejudice againſt the uſe hereof, he adds, that, " an unexperienced practitioner
" might, here, refuſe to preſcribe theſe medicines, becauſe of the ſuppoſed be-
" numbing quality of the opium; but the exceſſive heat of the climate, ſays he,
" requires it; and, beſides, we find it the only cure, in this caſe. But, opium, in
" theſe parts, is ſo prepared, that it may, ſafely, be given to infants; and, then,
" 'tis ſo uſeful, that, tho' it may ſeem ſurprizing, we can do nothing in hot
" diſeaſes without it." The uſe of cold water is, commonly, forbid in a dropſy; yet the *Spaw* is famed for curing that diſtemper. And, I know a perſon of great quality, who, in a caſe complicated with this, in a great degree, being thought incurable by her phyſician, ſurprizingly recover'd upon drinking the water of *Tunbridge*. So hot a wood as guaiacum, is, I believe, generally thought a dangerous medicine in a phthiſis; yet ſome eminent phyſicians, and, particularly the *Spaniſh*, relate wonderful cures, perform'd by the continued uſe of a decoction thereof, in deſperate ulcers of the lungs. And a very learned phyſician of my acquaintance, confirms this to me, from his own experience, in conſumptions. Mercury is thought prejudicial to the nerves, and brain; yet, one of the happieſt phyſicians I know, owns, that he, very ſucceſsfully, uſes preparations thereof in the palſy, and ſimilar caſes. And, I remember a gentlewoman, confin'd to her bed, with the palſy on one ſide, upon taking a doſe of a mercurial preparation, corrected with gold, which I gave her eminent phyſician, for that purpoſe, tho' it only purged her gently, was enabled, the day following, to walk about the room.

Thirdly, many things that ſeem, when firſt purpoſed, to be contrary to reaſon, are, afterwards, found very conſiſtent therewith. There are, ſome ſubſtances, which, tho' they appear ſimilar, or homogeneal, are endow'd with different, or contrary, qualities; as we ſee, not only from a chymical analyſis of bodies; but, alſo, where no fire is applied. Thus, rhubarb, being taken in ſubſtance,

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ſtance, the ſubtile part thereof proves purgative, and the terreſtrial aſtringent. Nay, if the parts, which have the leaſt ſhare in the conſtitution of the whole concrete, happen to meet with a body diſpoſed to receive their impreſſions; 'tis very poſſible, they may operate more ſtrongly thereon, than thoſe whereof the eye judges it altogether to conſiſt. And this I have made appear, by ſhewing, that ſallet-oil, which is thought to conſiſt of fat, and unctuous particles, contains, alſo, ſome that are ſharp and corroſive, which, happening on a proper ſubject, operate more powerfully than the former. For, keeping ſome pure olive-oil, a ſmall time, upon filings of crude copper, in a gentle heat, the liquor extracted a high tincture, between green and blue; which, therefore, diſſolved ſome part of the copper; as farther appears, from the recoverableneſs of the metal out of it. But to proceed; an ingenious chymiſt, whom I adviſed to bleed for a pleuriſy, which he refuſed to do, cured himſelf, only by *Helmont*'s laudanum, in two or three days: and by this means, he, alſo, ſince that time, cured ſome others, without phlebotomy. I am the leſs ſurpriz'd hereat, becauſe I have found, that, opium, duly corrected, is a great reſolver, and, ſometimes, proves ſudorific: nay, I, once, knew it do ſo, when other medicines, of that intention, fail'd. I have known coughs ſtrangely abated by a very ſaline medicine; wherewith, I, in a few hours, reliev'd a child, who by the violence of one, ſeem threaten'd with ſpeedy death; and, yet, many phyſicians condemn all ſalt things, in this caſe. And, from the vehemently pungent ſpirit of human blood, I have known, notwithſtanding its very ſaline, and heating quality, ſtrange effects, even in a deplorable, and hereditary conſumption. But, what ſeems more ſurprizing, a very ancient *Galeniſt*, eſteem'd as an oracle, *eſpecially in* pulmonic conſumptions, which were common in his country, having uſed various means to cure them, both in himſelf and others, confeſſed, he found nothing ſo effectual as ſulphur melted, and mixed with amber, and a cephalic plant, as betony, to allay the pungency of the ſulphur, and ſo ſmoked like tobacco. The ſulphur, however, was ſo predominant, that he kept a ſyrup in readineſs, to heal the ſoreneſs it might occaſion in the mouth. And, with the ſame remedy, a very curious perſon ſolemnly aſſured me, he had cured many conſumptions, particularly once in a lady, whom, even in health, I knew to be very lean. Now, phyſicians, generally, forbid the uſe of acids, when the lungs are ulcerated, or tender; and, yet, the fume of ſulphur is what condenſes into that highly corroſive liquor, called *Oleum ſulphuris per campanam*, which will, readily diſſolve iron. From hence it appears, either, that the theory of conſumptions it miſunderſtood; or, that the balſamic quality of the ſulphureous ſteam, is great enough to prevent the ill effects of its acidity. The dried livers, and galls, of eels, which are, uſually, remarked for nothing but their crudity, have, if we credit *Helmont*, prevented multitudes of women from dying of a hard labour. *Panarola*, alſo commends them for the ſame purpoſe; and, I knew a famous empiric, who got much reputation, and money, by ſelling this as a ſecret. I my ſelf, alſo, gave it to the wife of an ingenious phyſician, when he, and the midwives, had almoſt deſpair'd of her; and, as ſhe, afterwards, told me, each doſe made her throws, which before had left her, return; and that, at length, ſhe was deliver'd, ſhe ſcarce knew how. But, I, here, found the quantity of a walnut of the powder, which is double

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to that of *Helmont*, neceſſary for a doſe, in rheniſh, or white-wine, upon an empty ſtomach.

Did not experience aſſure us of the contrary, one wou'd think, that, to ſuffocate ſcorpions in oil, ſhou'd make it venomous; which, yet, is the cure of their poiſon: an effect, now the phyſicians find it true, they pretend to account for. The flux is endemial in *Ireland*; but, conſulting an ancient and experienced phyſician, there, concerning it's cure; he aſſured me, he found nothing more effectual, than freſh butter, melted, purified, and given in a large quantity; which ſeems more apt to cauſe, than cure, that diſtemper. And another ancient phyſician, there, afterwards, greatly commended it to me, in the ſame caſe.

Specifics, how they may operate.

I ſhou'd no longer inſiſt upon the recommendation of ſpecifics, did I not find, at every turn, that learned men, and, eſpecially, a famous foreign univerſity, reject them, for not knowing the manner of their operation; believing it abſolutely improbable, that a medicine which muſt paſs thro' ſeveral digeſtions, and circulate with the blood, ſhou'd neglect ſome, and befriend other parts of the body. To this objection I wou'd offer two things. And, firſt, I demand of theſe gentlemen, an intelligible explanation of the manner wherein the common medicaments operate; as how rhubarb purges choler, and hellebore melancholy, rather than other humours; how *Antimonium diaphoreticum*, and *Bezoarticum minerale*, after having long endured the fire, come to be ſudorific; how the infuſions of *Crocus metallorum*, and glaſs of antimony, tho' they have no manifeſt power to vellicate the tongue or palat, are both, violently emetic and cathartic; and, laſtly, how mercury, which, in many caſes, is given, with ſafety, to women in labour, *&c.* beſides having many other abſtruſe, medicinal qualities, becomes not only emetic and cathartic, but alſo ſalivates? For I muſt confeſs, that many of the vulgar operations of common drugs ſeem not to me, ſatisfactorily explain'd by phyſicians, who even are at a loſs, in accounting for the effects of diuretics, ſudorifics, narcotics, and many other familiar medicines, which, thoſe who conſider them only ſuperficially, think they underſtand. Nay, I greatly queſtion, whether the generality of phyſicians can, yet, give a ſatisfactory reaſon why any ſort of medicine purges in general. But he who will ſhew me where either the *Galeniſts* or *Peripatetics* have, clearly, made out why rhubarb purges choler, and ſena phlegm, *erit mihi magnus Apollo*; for I cannot conceive how their narrow and barren principles ſhou'd do it. And the only reaſon, that I can find, why phyſicians, who are ignorant of mechanical philoſophy, think they know ſuch things, is, becauſe they never, attentively, enquired about them. Secondly, a due application of mechanical philoſophy will, perhaps, more eaſily ſhew, at leaſt in general, that ſpecifics may produce the effects which judicious and experienced men have aſcribed thereto, than the vulgar principles can account for the moſt obvious and eaſy operations of medicines. And tho' the objection urged to prove, that ſpecifics cannot affect only particular parts, lies equally ſtrong againſt poiſons proving noxious to particular parts; yet experience demonſtrates that theſe, actually, prove hurtful to ſome parts, without equally, if at all, offending others. Thus cantharides affect the kidneys and bladder; quick-ſilver, the glands in the throat; *Stramonium*, the brain; and opium, the nerves and animal ſpirits.

Now if the body, as we have made it appear, is a machine, and medicines operate upon it accordingly; 'tis not ſtrange there ſhou'd be therein ſeveral ſtrain-

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ers of different textures, with, perhaps, local ferments in particular parts; and, the maſs of blood, continually flowing thro' the whole, that a medicine ſhould be convey'd from one part to another, by means thereof, and, at length, arrive to the parts or humours which their textures, the ferment abovemention'd, or ſome other mechanical properties, fit and diſpoſe to be operated upon, thereby. Saline and tartareous aliment, whilſt circulating in the maſs of blood, may, thereby, be diluted, and kept aſunder, ſo as not to offend any part, till it comes to be ſecreted in the kidneys, when, by its pungency, it may wound the ureters and tender bladders of thoſe afflicted with the ſtone: and upon this account, perhaps, cantharides only affect the bladder. Thus, alſo, a ſpecific may by diſpoſed to diſſolve in the body, and either preſerve or acquire a proper diſpoſition for the pores of the kidneys, liver, or other ſtrainer; or its particles may be endow'd with a figure and motion fit for adhering to thoſe of the peccant matter, (which, thro' their vehement agitation, or other offenſive qualities, diſorder the body,) and, by altering their bulk and ſhape, give them new and innocent properties. Another ſpecific may diſſolve the groſs and ſlimy matter obſtructing the veins; as I have obſerv'd that ſpirit of hart's-horn, which powerfully opens obſtructions, and reſolves viſcid phlegm, in the lungs, will, alſo, diſſolve, tho' more ſlowly, flowers of ſulphur, crude copper, &c. It may, alſo, obtund the acid ſpirit that cauſes coagulations in the blood, and reſtoring this to its fluidity and circulation, prevent formidable diſeaſes that ariſe from it, when ſizy. On the contrary, the minute parts of ſome ſpecifics may thicken and fix the too thin and fluid parts of the blood, or peccant matter, by aſſociating themſelves therewith; as the agile parts of pure ſpirit of wine will coagulate with thoſe of rectified ſpirit of urine, and alſo with another liquor I make, into a kind of ſoft, but ſolid ſubſtance. Nor is it hard to conceive, that a ſpecific ſhou'd work upon one part of the body, and not upon another. We have, already, inſtanced in vinegar, which diſſolves the ſhell, and leaves the skin of an egg, untouch'd; and if coral be thrown into common rectified ſpirit of tartar, the greater part of that fluid will remain unalter'd; but acid particles will, immediately, incorporate therewith, and thereby loſe their acidity: and this effect, coral has been obſerved to produce in human bodies, the acid humours being, perhaps, brought, by the blood, into the ſtomach and guts, whilſt that remain'd therein. But, in other caſes, the operations of remedies may be more ſudden, by diffuſing themſelves, at once, thro' the maſs of blood, and aſſociating with, and deſtroying, the acid particles. Thus, ſpirit of urine, put to that of tartar, only coagulates with, and affects, the acid therein contain'd; whilſt the ſpirituous, and phlegmatic parts remain as they were. And, ſurely, if ſome cathartics purge electively, as our opponents aſſert, and ſome antidotes are adapted to ſome poiſons, as experience manifeſts; ſpecifics may be allow'd, to act after the ſame peculiar manner.

Phyſic ſtill improveable by experience.

More examples, of the efficacy of ſpecifics, might be here produced, but theſe may ſuffice at preſent; eſpecially, if we conſider, that as phyſic owes its origin to experience, ſo thoſe who practiſe it, muſt enlarge and rectify their principles by the new diſcoveries that are made, either in art or nature. The old empirics, as we find them ſpeak in that excellent preface of *Celſus*, fully expreſs my ſentiments on this head. "Thus," ſay they, "phyſic gain'd ground, by obſerving

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"from the recovery of ſome, and the death of others, what was ſalutary, and "what was noxious; and, after remedies were found, men began to argue about "them; for phyſic was not the invention of reaſon." And to this purpoſe *Ariſtotle* excellently ſays, "where the fact is plain, tho' it appear improbable, "we ſhou'd not reject it; but enquire into the cauſe thereof." 'Tis true, credulity is of very pernicious conſequence in a phyſician; yet the world is little obliged to thoſe who, rigidly, confine the operations of nature to their own narrow limits; without allowing, either themſelves, or others, to try, whether ſuch things are performable, as they never ſaw done, and their common ſchool-principles cannot account for. 'Twou'd have ſeem'd incredible, a few years ago, to thoſe who were only acquainted with vegetable cathartics and emetics, that a cup, made of a ſubſtance, inſoluble by the ſtomach, ſhou'd, without any ſenſible diminution of its weight, communicate a ſtrohg cathartic, and emetic, quality to any liquor pour'd therein; and, notwithſtanding, diſcover no alteration, either in its colour, ſcent, or taſt, yet, a ſlight preparation of antimony, with ſalt-petre, or, ſingly melted into glaſs, will do this. And thus, alſo, which ſeems more ſurprizing, the common *Crocus metallorum* is ſaid, in a ſmall quantity, to render wine as ſtrongly emetic, as if a greater had been therein infuſed. That a fixed ſtone, capable of ſuſtaining the heat of a reverberatory fire, being taken in the quantity of about half a dram, and continued for ſome days, ſhou'd conſolidate broken bones, might ſeem impoſſible, were it not well known, that the *Lapis oſſifragus*, or, rather, *Oſteocolla*, as 'tis deſervedly call'd, has this property. *Quercetan* relates ſuch wonderful cures done by it, uſed both internally, and externally, in fractures, without the uſual ſymptoms, and in four or five days time, that, he tells us, it might ſeem incredible, had not other proper perſons beheld the ſame, as well as himſelf: and well might he ſay thus, ſince, as chirurgeons obſerve, nature is, uſually, forty days in forming a callus in the bones. *Matthiolus*, *Fabricius Hildanus*, and *Sennertus*, alſo, confirm this great virtue of the ſame medicament; and the latter tells us, that, "in youth, and a good habit, it cauſes the callus to grow too faſt, for which "reaſon, ſays he, it ſhou'd, only, be uſed in grown perſons, and not too free-"ly." And, that this caution is juſt, I was, lately, convinced, by a learned phyſician, who had ſtudied the nature of the ſtone, and told me, that his mother, having formerly broke her leg, ſuddenly occaſion'd an exorbitant callus, by taking too much of it. He, who, before the ſalivating property of mercury was diſcover'd, ſhould have told ſuch phyſicians as our opponents, that, beſides the uſual ways of evacuation, there was a ſort of remedy, which, operating by the ſalival glands, cured diſtempers, that were incurable by ordinary means, wou'd, I queſtion not, have been laugh'd at; yet this property is, now, indiſputable, and has proved ſo ſucceſsful, in venereal diſtempers, that I wonder thoſe who ſcruple not to uſe rough methods of cure, have not, yet applied it in ulcers of the kidneys, conſumptions, palſies, *&c.** wherein, I am inclin'd to

* This has, of late been, abundantly, perform'd in *France*, where they freely uſe the mercurial frictions in ſuch caſes, and with great ſucceſs. But an exact hiſtory of the cures, perform'd by mercury, applied in this manner, having never been publiſh'd, the *Engliſh* are more ſhy of it than, perhaps, they otherwiſe wou'd be. However, we can produce inſtances, among ourſelves, of very ſtubborn and radicated caſes, which have given way to mercurial unctions, when other remedies had failed.

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think, it might prove as effectual; eſpecially, if the tormenting ſymptoms of the ſalivation, which are ſcarce ſupportable, could be prevented. And, if mercury be dextrouſly precipitated, by a long and competent digeſtion, with a due proportion of refin'd gold, experience has inform'd me, that it ſalivates with much more eaſe to the patient, than the common mercurial preparations *. Beſides, I am inclin'd to believe, from trials, which I have procur'd experienced phyſicians to make, both in venereal, and other, diſtempers, that medicines, wherein the quick-ſilver is well corrected by gold, may have extraordinary effects. I cannot, here, omit an uncommon cure, perform'd with mercury, related to me, by the chymiſt to the king of *France*. A perſon of quality, Monſeignior *de Fatteville*, who commanded a *French* regiment of *Swiſs*, had a violent diſtemper in his eyes, which, notwithſtanding the utmoſt endeavours, both of phyſicians and chirurgeons, grew, in a few months, to a total blindneſs; in this ſtate he continued for many years, 'till hearing of a famous empiric, *Adrian Glaſſmaker*, who perform'd ſtrange cures, with a certain powder; the colonel went to him, and, reſolving to undergo the torment of his method, the empiric undertook him, and order'd about a grain of his mercurial powder, a kind of turbith, made by precipitating quick-ſilver with oil of vitriol, *&c.* to be ſnuffed up each noſtril, which, immediately, operated in a violent manner, by vomit, ſtool, ſweat, urine, ſalivation, and the lachrymal glands, for twelve hours together; cauſing, alſo, his head to ſwell greatly; but within three or four days after this ſingle doſe had done working, the patient began to recover his ſight; and, in a fortnight's time, ſaw better than ever, or, than men uſually do. The colonel purchaſed the receipt of the powder, and preſented it to Monſ. *Benoeſt*, a chirurgeon, who cured him of a broken thigh, when others were proceeding to amputation; and he, by uſing it, in the ſame manner, cured a gentlewoman of a cancer in her breaſt.

It will appear ſtrange to ſome perſons, that, in this whole diſcourſe, I have not once touch'd upon univerſal remedies: the reaſon is, I am not well ſatisfied about their poſſibility. Yet, methinks, we confine our thoughts too much, if we don't expect, that a generous medicine ſhould cure more than one kind of diſeaſe. The theory of diſtempers is not, yet, ſo accurate and certain, that we ſhould neglect the manifeſt, or promiſing virtues of noble remedies, where we cannot reconcile them thereto. A tranſlation of the morbific matter, from one part to another, frequently occaſions different diſorders. Thus I have obſerv'd the cauſe of a cough, removed from the lungs to the brain, has produced a ſudden decay of memory, and the reaſoning faculty, together with a partial palſy. It ſeems probable, therefore, that a medicine, endow'd with proper qualities, may operate upon the morbific matter, wherever it can meet therewith; and ſo effect a cure. It, alſo, frequently happens, that diſeaſes, to appearance, of a-

Univerſal remedies.

* To obtain the full virtue of mercury, without raiſing a ſalivation, were a very deſirable thing. This is attempted by ſome phyſicians, and, particularly, by thoſe of *Montpellier*, in the way of frictions, which they apply, at ſuch diſtances of time, as to prevent the riſe of a flux at the mouth. The chancellor of that univerſity, M. *Chicoyneau*, has publiſh'd a theſis upon the ſubject; wherein he, earneſtly, recommends the practice, and produces ſome inſtances of it's good effects, from his own experience.

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quite contrary nature, proceed from the ſame cauſe, differently circumſtanced; or that various diſeaſes, which ſeem original, are only ſymptomatic. Thus a dropſy, and a flow fever, ſeem oppoſites; yet an expert phyſician knows they may, both, proceed from the ſame cauſe, and have the ſame cure. An ignorant phyſician would think the numerous ſymptoms in hyſterical women, original diſtempers; and they have, often been, unſucceſsfully, treated accordingly; when uterine medicines would allay them, all at once. I lately knew a practitioner, who uſed the ſame volatile ſalt in dropſies, and original fevers; and a prepation of hart's-horn, not much unlike it, has, by me, been found equally ſerviceable in primary coughs and fevers. And we have, already, enumerated various remedies, which prove effectual againſt diſeaſes, judg'd, from the common theory, to be oppoſites; not here to mention my own obſervations on *Helmont's Laudanum*, my *Ens Veneris*, and the lady *Kent*'s powder. Many diſtempers that appear of contrary natures, are, if we may credit *Henricus ab Heer*, yearly cur'd by the *Spaw*-water; and of theſe he gives us a long detail. But after having expreſly aſſerted theſe waters to have the virtues, both of hot and cold minerals, and that the ſame, as well as different patients, are, accordingly, cured, both of cold and hot diſeaſes; he gives an inſtance to confirm it. "Theſe waters," ſays he, "among their other good effects, are excellent to "bring down the menſes, as I have, a thouſand times, experienced; and, "yet, they reſtrain them, when violent, better than any medicine whatſo-"ever." And I, lately ſaw, at *Tunbridge*, ſomething that ſeems to countenance what this experienced author delivers of the *Spaw*. Thus, then, we ſee, one potent remedy may cure ſeveral, ſuppoſed, contrary diſeaſes. And it deſerves to be farther obſerv'd, that when the receiv'd practice fails, the tired and deſpondent phyſician ſends his patient to the wells, in hopes that a remedy, prepared by nature, may do more than thoſe prepared by art. This obſervation, being well conſider'd, together with the poſſibility there is that art may meliorate and improve moſt remedies, afforded by nature, one might dare to hope, that medicines of greater efficacy, may be prepared, and applied to more caſes, than thoſe who admire the common, arbitrary theory of diſeaſes, and judge of remedies by what is ſold in apothecaries-ſhops, expect. My deſign, however, is not to ſubvert thoſe principles of the *methodus medendi*, wherein all phyſicians, unanimouſly, agree; much leſs would I countenance thoſe bold empirics, who, without a competent knowledge in anatomy, botany, and the hiſtory of diſeaſes, think receipts, alone, can enable them to cure diſeaſes which they don't underſtand. No, through the whole of this diſcourſe, without, peremptorily aſſerting any thing, I have barely repreſented my notions, as deſerving an impartial conſideration; ſo that, in caſe they are rejected, it may not be, before the things have had a fair trial and examination; but that, if they happen to be approved, they may ſerve as inſtances of the uſefulneſs of natural philoſophy to phyſic: and if any thing I have ſaid, may conduce to that end, I ſhall think my time well ſpent in this ſtudy. Man is ſo noble a creature, and his health ſo requiſite to his well being, and the diſcharge of his ſeveral duties, that I wonder not the heathens aſcribed the art of healing to the gods, and advanced it's happy profeſſors among them. The principal end, for which I ſtudy chymiſtry, is to relieve ſome languiſhing patients the more eaſily

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from their ſickneſs; for, certainly, our common remedies are very ineffectual; not to mention the fatigue they occaſion in taking. We daily meet with too many, who, like the woman in the goſpel, have "ſuffer'd many things "of many phyſicians," and ſpent their whole ſubſtance upon them, without being ever the better, but rather worſe; for which reaſon, I eſteem the inventing and divulging uſeful things in phyſic, and the recommending of good remedies, among the moſt extenſive acts of charity, whereby a man becomes, really, more ſerviceable to the world, than by building an hoſpital. What numbers have owed their health to mercury; and, conſequently, how many more perſons are obliged to *Carpus*, or whoever diſcover'd it's uſe, than have recover'd in the largeſt hoſpital, in the world?

I am ſenſible, indeed, 'tis reputed more faſhionable, in young gentlemen, to get into the army, and to kill their fellow creatures, than to cure them; and that 'tis thought a fine exerciſe to deſtroy the nobleſt workmanſhip of nature; but the character of our great maſter was "that he went about doing good, "healing all manner of ſickneſs, and all manner of diſeaſes among the peo-"ple;" which is an employment worthy even the nobleſt of his diſciples.

PART III.

Shewing the advantages of natural philoſophy to human life.

SECT. I.

Naturalphiloſophy tends to reform, and improve trade.

I COME now to ſhew how naturally philoſophy contributes to afford us the neceſſaries and conveniencies of life; whereby our empire is extended abroad, as a knowledge in phyſic, ſecures us at home. And, methinks, it appears highly probable, that good naturaliſts may greatly reform trade, or improve it; ſince, in general, it depends, only upon a ſmall number of particular productions of nature; and, chiefly, lies in the hands of the illiterate. Thus for inſtance, the huſbandman's ſkill conſiſts in the knowledge of a few plants and animals, their relation to particular ſoils, and management, with the influence of the celeſtial bodies and meteors thereon; all which ſubjects fall, properly, under the cognizance of a naturaliſt. He, therefore, who has attentively conſider'd the nature of generation, nutrition, and accretion, both in plants and animals, and knows how to vary an uſeful experiment, ſo as to remedy the inconveniencies, or ſupply the defects thereof, and can, dextrouſly, apply his own, and others obſervations, may cultivate huſbandry to as much advantage as the ordinary farmer tills his land. An attentive conſideration of the parts that conſtitute each particular trade, would ſhew how they all depend upon philoſophy, and might be farther improved. Thus, the principal parts of refining, are a knowledge of the preparation of *Aqua fortis*,

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and its operation upon ſilver, copper, and gold, with the means to purge it, that, neither gold may be diſſolv'd, nor ſilver precipitated, when diſſolv'd thereby; to know what proportion is diſſolvable therein, and the quantity of water, neceſſary to weaken the ſolution; how long copper-plates ſhould lye to precipitate the ſilver it contains; how lead is colliquated with, and what proportion thereof is requiſite to carry off, the baſer metals upon the teſt; how cupels are made, and, with theſe, to draw off lead, or antimony, from ſilver, or gold; to diſcern when the metal is, ſufficiently, refin'd; and, laſtly, to know the proper proportion of gold, and ſilver, to make water-gold*. This trade, indeed, is underſtood by few, and not ſo diffuſive and complicated as hundreds of others; yet, if they all were judiciouſly reſolv'd into their component parts, it would, doubtleſs, appear, that moſt of them are, only, corollaries, deduced from particular obſervations in philoſophy, or the bare application thereof, to the uſes of human life. And, if ſo, 'tis very probable, that farther diſcoveries in the nature of the materials, the ſubjects of trade, and a knowledge of the laws they obſerve, may reform, or meliorate, ſeveral of it's Branches. This, too, is performable by odd and unſuſpected means; ſo that, perhaps, the chymiſt's charcoal, may prove an excellent equivalent for manure; if a vegetable ſalt, as probably it is, be the cauſe of the land's fertility. For, chymical experiments may diſcover the nature hereof, and, thereby, afford uſeful directions towards the melioration of arable, paſture, and wood-land. From the experiments I, myſelf, have made upon earths, dungs, and ſeeds, whereby, I found, that ſalts abounded in the liquors they yielded; I ſee reaſon to wiſh this inquiry were farther proſecuted, towards the improvement of huſbandry. Whoever has obſerv'd thoſe many particulars in this art, which cauſed Sir *Francis Bacon* to pronounce nitre to be the life of vegetables; and, conſiders; how land is improved by pigeon's dung, which impregnates it with ſalt-petre; and, laſtly, knows, that moſt fat earths, defended from the ſun and rain, and left to themſelves, will, ſoon, abound in nitrous ſalt; whoever, I ſay, conſiders theſe things, will, perhaps, believe an inquiry into the nature of ſalt-petre, may be of great uſe in farming.

Land improveable by means of chymiſtry, hydroſtatics, &c.

I, once, cauſed ſome earth to be dug up, from under a pigeon-houſe, and diſtilling it, in a retort, little, or no oil, but a conſiderable quantity of a reddiſh liquor came over; ſo far unlike ſpirit of nitre, that it greatly reſembled volatile ſalts; for, without being rectified, it not only turn'd ſyrup of violets green, and precipitated a ſolution of ſublimate, into a milky ſubſtance; but there, alſo, came over, therewith, into the lower part of the receiver, a dry ſalt, in taſte like the volatile kind, and ſo far an alkali, that it readily hiſſed, and cauſed an ebullition in an acid menſtruum. From hence, it ſeems, which is highly remarkable, that a ſalt, very different from acid, may by the operation of the earth and air, be ſo alter'd as, afterwards, by a ſlight management, to afford ſalt-petre, whoſe ſpirit is ſtrongly acid. And dropping *Aqua fortis* upon pot-aſhes, diſſolv'd in a little fair water, 'till the ebullition and hiſſing

* For a particular account of this art, ſee *Philoſophical Tranſactions*, N° 138. p. 955. and 142. p. 1046

were

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were perfectly ceaſed; and, having filtred this liquor, and ſet it in an open veſſel to evaporate, with a gentle heat; being, in two or three days time, removed to a cold place, it afforded very pure cryſtals of ſalt-petre.

I might add, that the knowledge of the nature, and diſtinctions of ſaline bodies, may, greatly, aſſiſt, to ſhew the differences of the various ſaltneſs that is found in ſoils; and with what ſort each plant, or ſeed, is moſt delighted. By this means, many tracts of land, now thought barren, for want of a knowledge hereof, might be render'd uſeful. And ground may be made to yield much better crops, than uſual, by being, ſucceſſively, ſown with a proper variety of ſeed, agreeable to the nature of the particular ſalt, at preſent, inherent in the earth; for, by the abſence of one kind of ſalt, it is better prepared to feed thoſe plants that delight in another. And of this, the huſbandmen have, in ſome meaſure, already taken notice; as appears by their ſowing turneps, in grounds too remote for the convenient carriage of compoſt, to ſerve for manure, and fit them for wheat. And, I am of opinion, that any land, except mere ſand, might, without much culture, be made fertile, were we but well acquainted with the ſoil, and provided of the various ſorts of grain, that nature affords, in different countries. There are various ſoils, both in *England*, and elſewhere, left quite uncultivated, wherein ſome foreign vegetables might thrive and proſper. Many large tracts of ſteep and craggy land, expoſed to the ſouthern ſun, lye waſte, in ſeveral hot countries, where grapes are not planted; tho' in *France*, *Italy*, and, even on the *Alps*, ſuch lands are turn'd into excellent vineyards. An experienced way of cauſing wheat to grow, and proſper, even in clay, where no grain had thriven, was communicated to me by a perſon who had uſed it: and the art conſiſted in ſteeping the ſeed, for a determin'd time, in a certain expreſs'd oil that is not dear; whence, 'tis probable, that, without altering the ſoil, a ſlight change, properly made in the ſeed, alone, may ſo fit them, for each other, as to yield a large increaſe. I have, alſo, ſeen, in a collection of rarities, an ear, or two, of corn, not much unlike our common wheat, one grain whereof, in a warm country, from whence this was brought, would afford ſo vaſt an increaſe, that the poſſeſſor was, almoſt, aſhamed to declare; and, I am more afraid to repeat it. An *Engliſh* gentleman, however, aſſur'd me, that having ſown ſome of this corn, in land of his own, he found a ſingle grain to produce ſeveral hundreds; tho' that came nothing near what it was ſaid to do, in a more ſuitable ſoil and climate. The learned *Acoſta* affirms, that, in ſeveral parts of *America*, where the *European* wheat will not proſper, the *Indian*, or *Virginian* ſort, call'd, alſo, *Maiz*, ſucceeds ſo well, that tho' the grain be large, and more than one cluſter often found upon one ſtalk; yet, in a ſingle cluſter, he has counted ſeven hundred grains. He adds, 'tis not unuſual, in that country, to reap three hundred times the quantity ſown. This, indeed, ſeems, a little incredible; but I, myſelf, have found, even in *England*, ſuch a multitude of grains, in one of the vaſt number of ears, produced from a ſingle grain, that I am inclin'd to abſolve *Acoſta* *.

* For the improvement of agriculture, ſee *Philoſophical Tranſactions*, No. 116. p. 359. No. 225. p. 412. No. 237. p. 44.

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In ſome *Eaſtern* countries, a ſort of rice, the chief food of the natives, thrives, excellently, upon land ſo watery, that the perſon is there obliged to wade, who ſows it. Yet, this is leſs ſtrange than what *Martinius* tells us, as a practice in ſome parts of *China*; where many places, that lye, all the year, under water, have ſeed ſo well appropriated to them, that, tho' thrown in the water, as baits for fiſh, it ſhoots up in it's proper ſeaſon, appears on the ſurface, like a verdant field, and affords a plentiful crop.

To proceed. Chymiſtry and hydroſtatics may help to diſcover the kinds and degrees of ſaltneſs, reſiding in ſeveral other bodies, the huſbandman employs. I, myſelf, have made ſurprizing diſcoveries, in working upon ſome ſorts of earth, by chymiſtry. And, as in particular, the fertility of manure, ſeems to depend upon it's ſalino-ſulphureous parts; a practical enquiry into the differences and various operations of ſalts, may, probably, aſſiſt to diſcover various kinds of compoſt, with the proper manner, wherein to multiply, compound, and apply them.

And, thus, not only, fire, but water, by means of the engines, and contrivances to be learnt from hydroſtatics, may be made more ſerviceable to huſbandry than ordinary. *Martinius* aſſures us, that, in one province of *China*, they water their rice-fields, by means of moveable mills, placed, as occaſion requires, upon any part of the banks of a river. The wheels, here, raiſe the water, in buckets, to a great height, above the ſurface of the river; whence 'tis, afterwards, convey'd to the deſtin'd places, in proper channels. But, the art of levelling, or conducting water upon the ground, may be, farther, ſerviceable in this caſe. For ſoils, ſuited to this way of culture, are, thereby, greatly improveable; tho' it be, almoſt entirely, neglected, both in *England*, and elſewhere. Some ground of mine, by being ſkilfully overflow'd, has doubled it's increaſe. And I have, alſo, ſeen a wild boggiſh place, turn'd, by a perſon of quality, into a good dry and compact ſoil, by, barely, trenching and overflowing it equally, ſix or ſeven times in a year, between the beginning of *October*, and the middle of *April*, with water from a neighbouring ſpring, that is enrich'd by no land-floods, and roſe in a barren and uncultivated place; ſo that this ground afforded hay, in ſuch plenty, as to become worth twenty times it's former purchaſe. Other inſtances, of the like improvement, I have met with, from, ſkilfully, overflowing grounds with common water.

I muſt here obſerve, that the more comprehenſive any trade is, the more improvements it will admit of from philoſophy; becauſe, depending upon many natural productions and operations, there muſt ariſe many particulars to be meliorated, or reform'd, either in the manufacture, or profeſſion. Thus corn, in huſbandry, renders a knowledge of the whole art of tillage convenient, with the ways to order cattle, the dairy, an orchard, a kitching-garden, wood, flax, hemp, hops, bees, *&c.* and the particular productions of ſome of theſe, as honey, cyder, *&c.* are capable of improvement, and require ſkill to manage. In the variety of particulars, therefore, wherewith the huſbandman deals, there muſt be ſome, wherein the ſuperior knowledge and experience of the naturaliſt, will be ſerviceable. And, as one of the principal parts

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parts of huſbandry depends upon preſerving cattle from diſeaſes, and the fruits of the earth, from putrefaction; natural philoſophy may conduce to both theſe ends. He who can accelerate, and delay putrefaction in bodies, may ſhew the huſbandman how to prepare variety of manures; to enrich his ground with the peculiar kind of ſalt it wants; and, alſo, how to preſerve ſeveral ſeeds, flowers, and fruits, beyond their natural duration. Thus many, by my recommendation, have continued fruits, as quinces, for inſtance, good, almoſt, all the year round, by a pickle made, only, of water, and the refuſe of quinces, or what is eaſily obtain'd from them: but cherries, I have preſerved freſh and juicy for more than a year: and that without ſalt, or ſugar, only by a proper ſpirit of wine, well impregnated with the tincture it drew from the ſkins of the ſame kind of fruit.

The great advantage accruing to the *Dutch*, from the beſt way of pickling herrings, and to others, from ſo ordering the fleſh of animals, as to keep ſweet, in paſſing from *Europe* to the *Eaſt-Indies*, and, ſometimes, even 'till it comes back again from thence, may ſhew what benefit huſbandry might receive from diſcovering means to preſerve the productions of the earth; but, eſpecially, if it could be extended to ſmall wines, cyder, perry, &c. that are, commonly, made in large quantities; but ſoon decay, at home, and are unfit to be tranſported to very diſtant countries. The virtue of ſugar, to ſtrengthen vinous liquors, and render them durable; and the method of preſerving great variety of fruits, and the juices of plants, without the help of ſalt, or any thing ſharp, give ſome reaſon to expect, that very different ways may be found to make ſubſtances out-laſt their natural term of duration*.

Again, that great damage the huſbandman, often, ſuſtains by ſtubborn and contagious diſeaſes in his cattle, might, in good meaſure, be prevented by the inſtructions of the naturaliſt, eſpecially if ſkill'd in phyſic. For, as many diſeaſes, ſo, many cures, alſo, are analogous in men and brutes; tho' remedies, for ſeveral reaſons, uſually ſucceed beſt in the latter. A gentleman, of my acquaintance, has, for ſeveral years, preſerved his numerous flocks, in a moiſt country, when moſt of his neighbours loſt theirs, by the uſe of *Spaniſh* ſalt. After having bled them, a little, under the eye, he obliged them to take down, a ſmall handful of it, two or three times in a few days; without permitting them to drink any thing, for ſome hours, after it. This remedy he employ'd, at that ſeaſon, when there is a ſuſpicion the ſheep will begin to be bloch'd. I might here alledge, the virtue of crude antimony againſt the foulneſs of the blood, and leproſy in ſwine; of quick-ſilver, againſt the worms in horſes; of the remedy of *Palmarius*, which, he aſſerts, is infallible againſt the bite of a mad dog in cattle; of a more parable one, alſo, that ſerves, no leſs, in men, the effect whereof

Huſbandry by medicine, in curing the diſeaſes of cattle.

* To preſerve fruit and flowers for a whole year, take ſalt-petre, one pound, bole-armeniac two pounds, common clean ſand, three pounds; mix them together, and, in dry weather, take fruit, or flowers, of any ſort, not fully ripe, each with its ſtalk, and put them, ſingly, into an open glaſs, 'till it be full; cover it cloſe with oil-cloth, and, in a dry cellar, put each of theſe glaſſes four fingers deep, under ground, ſo that, quite round, above, as well as below, there may remain two fingers thick of the mixture. See *Philoſophical Tranſactions*, N° 237. p. 44.

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was experienced by a near relation of mine; of the antimonial cup, for several diseases in horses and sheep; and, lastly, of another antimonial medicine, very successfully used, by an acquaintance of mine, to fatten his horses after sickness; all these, and many more, receipts of medicines, highly, esteem'd for their efficacy in several distempers, both in men, and brutes, I might here set down, were it my present business.

And by philosophy in curing the diseases of the soil.

Moreover, there are many reasons assignable, why husbandry, with the assistance of philosophy, may be improved, by the addition of a therapeutic part, with regard not only to the animal, and vegetable productions it consists in; but, also, to the various distempers of the ground itself. For, were the causes of barrenness therein, with its respective indisposition to nourish particular plants, or animals, discover'd; many of those defects may, doubtless, be removed by rational applications, and proper means of cure; as we see in other inanimate bodies, and, even, metalline ones. And, from a knowledge of the particular cause of a barren soil, fertility may, perhaps, be procured to it, without much cost. Some ingenious husbandmen have, lately, declared themselves satisfied with a way of meliorating two of the most unfruitful kinds of land, clay, and sand, that consists only in skilfully mixing them, in a due proportion, according to the use for which it is design'd. And, an ingenious gentleman, to satisfy some curious persons, purposely, sow'd some corn, near the place of my abode, which prosper'd so strangely, that one root, whereof I took particular notice, tho', perhaps, not the most productive in the field, yielded sixty odd ears: and, what is more surprizing, this wonderful increase depended only upon a philosophical observation without any thing extraordinary having been done either to the ground, or the seed; for the secret was intrusted with me, by the gentleman himself, to make public, in case he died before me. And, with the same view, he communicated to me a method of increasing the bulk of apples in their growth, by help of the despised leaves of a very cheap, and common vegetable.

Trades conducing to the delight of mankind, improveable by philosophy.

To proceed. Not only the necessary trades, but also the pleasurable ones, are improveable by philosophy; for, they, chiefly, consist in the knowledge, and application, of some natural productions, and operations. And the things, by this means acquired, will, without changing their nature, serve us in different capacities; thus, wine quenches thirst, recovers a fainting person, and intoxicates: the same spirit of wine wherewith the physician draws his tinctures, and prepares his extracts, for medicinal purposes, will dissolve benjamin, for the ladies; which, mix'd with water, makes an excellent cosmetic; and the same spirit, when applied to the proper ingredients, produces several kinds of fine varnish: the tincture of benjamin, likewise, is applicable to the same uses, and is, itself, a pretty odoriferous varnish, and good against tetters, they being bathed therewith. That, knowledge, and skill, may make happy applications, even of unpromising things, to the delight of mankind, appears, evidently, from musical instruments; for, who wou'd imagine, did he not know it, that a few pieces of wood, joined together, and the guts of cats or lambs, twisted into strings, shou'd, when artificially struck, afford the most ravishing pleasure? I might, here, go on to instance in the art of colouring, perfuming, confectionary, and of preparing cosmetics, &c. did I not chuse to recommend philosophy,

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loſophy, from the pleaſure it affords the reaſon, rather than from the charm wherewith it bribes the ſenſes. Tho' what has hitherto been deliver'd, about the uſefulneſs of philoſophy to trades, belongs, chiefly, to thoſe wherein nature herſelf ſeems more concern'd than the artificer; yet ſuch are not here exempted wherein art has the greateſt ſhare. Theſe, indeed, rather depend upon the manual dexterity of men, than a ſkilful management of nature's productions, by operating on each other; yet, even here, the naturaliſt may be ſerviceable. Many manual trades, eſpecially as exerciſed in large towns, conſiſt of ſeveral parts, and require other trades to prepare, and diſpoſe their materials, before they can be finiſhed, and fitted for ſale. And, altho' the finiſher performs his part, by means of his hands, and tools; yet, the ſubordinate workmen, uſually, ſtand in need of ſome obſervations on the conditions of the body they deal with, or muſt elſe employ ſome phyſical operation; and herein they may be, greatly, aſſiſted by an intelligent naturaliſt. Thus, ſtone-cutting, tho' it ſeem wholly to conſiſt in ſhaping its materials, contains many particulars wherein I cou'd, eaſily, ſhew that experimental philoſophy wou'd be beneficial. For unuſual methods might be diſcover'd, as I can teſtify, to examine the nature, and goodneſs, of marble, alabaſter, or other ſtones. A competent knowledge of the ſap found in ſtones, to be employ'd in building, is ſo neceſſary, that experienced maſter-workmen have aſſured me, that ſtone dug at one ſeaſon, will ſoon moulder away, when the ſame ſort, taken out of the ſame quarry, at another, will endure the weather for many years, if not ages. The cements, alſo, and ſtoppings, as they call them, which are of great uſe, in this trade, may be improv'd by one who is verſed in ſuch kinds of mixtures. I remember, I once taught an inquiſitive artiſt a fine cement, for rejoining broken ſtatues; who, by the like means, in other caſes, cou'd counterfeit marble ſo well, that tho' large cavities were filled up with cement, the work wou'd paſs for entire; thoſe parts being undiſtinguiſh'd from natural marble. Want of curioſity keeps our ſtone-cutters in *England*, unacquainted with the ways of working upon porphire: for none of them will undertake, either to cut, or poliſh, it. Other countries, alſo, are ignorant herein; tho' it was in great uſe among the *Romans*; and, even now, at *Rome*, there are a few who make a very great advantage of this art. I am not certain what they employ for that purpoſe, but believe it to be powder of emery; for I have, in *England*, cauſed a porphire to be cut by means of that, ſteel ſaws, and water. Not here to mention, that I have an art to ſtain white marble with durable ſpots, ſmall or large, and of a red, or brown colour. But the art of ſtone-cutting depending greatly upon the goodneſs of the ſteel tools, which they muſt have from the ſmith, and the dealers in iron; if theſe trades were improved, it wou'd tend to the perfection of the other. And, that the ſmith's craft, however manual it appears, may be meliorated by a knowledge of nature, is not difficult to manifeſt. The ways of making iron, and ſteel, are not only improveable before they come to the ſmith's hands, but better expedients may, likewiſe, be deviſed for ordering them, when they come to be faſhion'd into weapons, and tools. The ſword-blades, and other weapons, made at *Damaſco*, are, every where, famed, (and that juſtly, as far as appears from

And particularly ſtone-cutting.

And ſmithery

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from some trials I have made,) for cutting asunder, even, iron itself; yet, it seems to be, only, the skill of the artificer that gives them this preheminence. Their goodness, indeed, might be presumed to proceed from something peculiar in the materials of that place, did not *Bellonius* inform us, they have no mines of their own; but receive all their iron and steel from other countries; the artists giving them this temper and perfection. In tempering of steel, it is reasonable to suppose, that, besides the goodness of the metal, and the particular degree of heat, which is all the workmen regard; the nature of the fluid, or other body, wherein the hot metal is plunged; and other proper methods of ordering it, may, greatly, contribute to bring it to perfection. I have met with a graver of so surprizing a temper, that all the known means, both I, and others, used, could not let it down; though no graver, made in *England*, could have withstood us. This was, afterwards, affirmed to have been tempered at *Damasco*. I am acquainted with a way to harden gravers, without quenching them in any liquor, tallow, or unctuous body; and, having recommended, to another, an uncommon method of tempering them, he brought me one, which, being plunged into a certain cheap mixture, had been harden'd, and temper'd, at once. And, what may seem more strange, tho' ignition, and extinction, in cold water, be the common way to harden steel; yet, by observing one certain moment of time, steel may, by this means, be made, surprizingly, soft. But farther, a curious maker of steel-tools, told me, he observ'd a difference between the use of pump and river water, in giving them their temper; each being fit for it's respective sort. Besides these, there are many other particulars, wherein iron and steel are improvable by the naturalist. And, first, the metal may be render'd so soft, as, by means of strong moulds, to receive variety of figures. This an eminent artificer assur'd me, he had seen done in iron, with considerable profit. Secondly, it may be render'd fusible; and I, myself, with a charcoal fire, and a flux-powder, compos'd of tartar, sulphur, and arsenic, have run it into an exceeding hard, and very polishable mass. Thirdly, it may be so order'd, as to continue, long, free from rust; and an ancient virtuoso, who purchased the secret, for a great prince, used to shew steel, so prepared by tempering it in water, impregnated with the bark of a certain tree. In a word, there are various other means, whereby iron and steel, or the trades that use them, may be meliorated: for the naturalist may advance an art, or profession, in abundance of respects; as, either, by discovering variety of materials, or, rendering those already in use, better condition'd; by detecting, and reforming, unheeded errors, or mistakes; by devising more easy, and compendious, methods of operation; by improving the auxiliary branches; by instructing the artificer to choose, examine, and preserve his tools and materials; or, lastly, by shewing how to make the ultimate productions sooner, cheaper, easier, or better; applicable to more uses, or more durable than usual; with other services, too numerous here to relate.

Philosophy may introduce new trades.

But farther, a naturalist may, likewise, introduce new trades, as well as improve the old ones; and, that, either, by inventing them originally, or bringing them into request, where they were unknown before: for neither nature, nor human invention, is so far exhausted, as not to afford them, were philosophy employ'd

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employ'd in the ſearch. We may here obſerve, that a trade, in many caſes, differs from an experiment, not ſo much in the nature of the thing, as it's having been, accidentally applied to human uſes, or made a buſineſs, by a company of artificers, in order to their own profit; which are things extrinſecal and accidental to the experiment itſelf. Thus, for example, the exploſion occaſion'd by a mixture of nitre, ſulphur, and charcoal, whilſt it paſſed no farther than the laboratory of the monk, the reputed inventor of gun-powder, was only an experiment; but, when once the great uſe to be made hereof became more generally known, and people reſolv'd to make a buſineſs of improving, and applying it; this ſingle experiment, at once, gave riſe to founders of ordinance, gun-ſmiths, engineers, and abundance of other trades.

The diſcovery of the polar virtue in the load-ſtone, has occaſion'd a diſtinct trade, the art of compaſs-making: and many other inſtances, of the like kind, might be produced; eſpecially, where mechanical tools and contrivances conſpire with the diſcovery of natural productions; ſo that, frequently, a very few mathematical theorems, or phyſical obſervations, reduced to practice, by the manual operator, become trades. Thus two or three dioptrical propoſitions, falling into mechanical hands, have introduced ſpectacles, teleſcopes and microſcopes. Quick-ſilver being obſerved to amalgamate with gold, and to be, again, ſeparable therefrom without diminution, produced the art of gilding; which, principally, conſiſts in mixing, by means of a proper heat, pure gold with five, ſix, or ſeven times it's weight of quick-ſilver, 'till it become of a conſiſtence fit to ſpread upon the ſilver or copper deſign'd. For the gold being, by this means, evenly overlaid, they can eaſily, by fire, force away the mercury; and, with a liquor, by them call'd colouriſh, wherein nitre, verdigreaſe, ſal-armoniac, and other ſaline bodies are diſſolved, reſtore it's luſtre to the remaining gold, which they, afterwards, make bright by poliſhing.

The ſlight, and obvious remark that a ſpring, phyſically conſider'd, was a continual and durable force, with it's corollary, that this force, properly applied, might balance the weight required to move the wheels of a clock, join'd to a ſuitable mechanical contrivance, produced thoſe uſeful machines call'd watches, which now afford a handſome ſubſiſtence to many dextrous artificers; and which, tho' cuſtom has render'd them familiar to us, were unknown to the ancients, and highly priz'd, and admired even in *China*, when firſt carried thither. The diſcovery that *Aqua fortis* diſſolv'd ſilver and copper, but would not work upon gold, added to the obſervation, that lead, melted with either of the noble metals, and then forced from them, by fire, will carry off with it any of the baſer ſort, has, in latter ages, produced the art of refining. The operations of ſome *Lixivia*, clays, and a few other common things, upon the juice of the ſugar-cane, has not only added to the ancient husbandry, the cultivation of theſe canes, but given birth to the ſeveral trades of ſugar-boilers, ſugar-makers, refiners of ſugar, and confectioners; not to mention the advantage it brings to the apothecary. But even a very ſlight contrivance, or manual operation, if it prove fortunate, may ſupply men with a trade, as we ſee in the art of printing. And the lucky trial made to bore very ſmall holes thro' broken *China* cups, with the uſe of ſlender wire, inſtead of thread, or ſilk, to faſten the pieces together,

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has given being to the exerciſe hereof, as a vulgar trade in the *Eaſtern* countries. Their art, alſo, of varniſhing, or japanning, as we call it, which, depending on a knowledge of ſome gums, and liqours in their country, employs multitudes of tradeſmen among them, is, as I am credibly inform'd, now practis'd at *Paris*. And, finding from *Linchoten*, that in *China* and *Japan*, they made this excellent varniſh of gum *Lacca*, I imitated one of the beſt ſorts of it, by diſſolving that gum in highly rectified ſpirit of wine, giving it a colour, and laying it on in a particular manner. I might, farther, alledge, the art of cultivating and gathering ſuger-canes, with the manner of ordering their juice, as a recent inſtance of the tranſplantation of arts and manufactures; for, as I am very credibly inform'd, it is not long ſince, that, in our memory, a foreigner, accidentally bringing ſome ſugar-canes, as rarities, from *Braſil* into *Europe*, touched at *Barbadoes*, where an *Engliſh* planter obtain'd a few of him, with ſome hints as to their cultivation and uſe; which, by the curioſity and induſtry of the *Engliſh* colony there, were ſoon ſo well improved, that the iſland became, and ſtill continues, able to ſupply *Europe* with ſugar. I am the more particular in this inſtance, becauſe 'tis very remarkable, and ſhews how many hands the introduction of a phyſico-mechanical art may employ: for the *Negroes*, who live as ſlaves upon that ſpot of ground, and are, almoſt wholly employ'd in the ſugar-trade, amount to between five and twenty and thirty thouſand ſouls. Nay, ſo prodigiouſly advantageous is this new art, both to particular perſons, and the public, that, one year with another, tho' the iſland be ſhort of thirty miles in length, there are imported for *England* ten thouſand tun of ſugar, each tun containing two thouſand pound weight; which amounts to twenty millions of pounds of that commodity. This account, tho' it may ſeem incredible, I have had confirm'd from very good hands.

Thus, then, it appears probable, that experimental philoſophy may multiply trades, as well as improve them. Nor do I deſpair, that among the means of increaſing trades, one may be the retrieving of ſome that were anciently practiſed, but ſince loſt; of which the learned *Pancirollus* gives us a catalogue. For, as the ſkilful diver brings up, not only pearls and coral, but, alſo, ſhipwreck'd merchandize; ſo the experimental philoſopher dives into the deep receſſes of nature, to recover inventions ſwallow'd up by the injuries of time, as well as to bring to light her hidden riches.

Every profeſſion, condition, and perſon, may be benefitted by philoſophy.

But, ſtill farther, I am inclin'd to think, there is no profeſſion, condition, or, perhaps, individual perſon of the ſpecies, that may not, one way or other, be advantaged, or accommodated, were all the truths diſcoverable by natural philoſophy, known and applied. So that, beſides thoſe inventions which are formed into trades, there may be a multitude of looſe particulars, whereby the naturaliſt might highly gratify, and aſſiſt mankind. The nature of the thing will ſcarce permit me to illuſtrate this aſſertion, without deſcending to inſtances trifling in themſelves, if not contemptible; for which reaſon I ſhall, here, content myſelf with a few.

A great lady, lately complaining that ſhe could not write, in the common way, without blacking her fingers; I deſir'd her to prepare her paper with a fine powder, made of about three parts of calcin'd copperas, two of galls, and one

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of gum-arabic, which, being freſh mixed, and rubbed with a hare's foot, into the pores of the paper; when that came to be wrote on with fair water, it would, immediately, diſcover black legible letters.

Having, ſeveral times, occaſion to make a word or two, lately written, appear as if written long before, I lightly moiſten'd them with oil of tartar *per deliquium*, more or leſs diluted with fair water, as I deſired the ink to appear more, or leſs, decay'd. Another cleanly way of writing, without ink, is by rubbing the fine powder of exquiſitely calcin'd hart's-horn, clean tobacco-pipes, or rather mutton-bones, burnt to a perfect whiteneſs, upon the paper, and, then, uſing a ſilver bodkin, or the like, as a pen. A very ſimple and eaſy method of making white table-books, is to temper pulverized ceruſe, with a ſtrong ſolution of gum-arabic, in water, which being brought to a thick conſiſtence, muſt be rubbed over the paper, and ſuffer'd to dry. A very ingenious artificer, having contrived an uſeful engine, a neceſſary part whereof was a glaſs, filled with fair water, and ſtopt, complaining that frofty weather, by freezing the water, broke his glaſs; I adviſed him to uſe good ſpirit of wine, inſtead of the water, or, to ſave the expence of that, ſea-water, ſtrengthen'd with a little ſalt; or, laſtly, common ſpring-water, with a twentieth, or tenth part of ſalt diſſolv'd therein; for I have found none of theſe, tho' clear, to freeze in the ſharpeſt of our winters in *England*. I, once, ſhew'd a perſon of quality an eaſy way to ſend a written meſſage which the bearer could not diſcloſe: this, I perform, by writing on the meſſenger's back, with a clean pen, dipt in my own urine; (but, to my ſurprize, the experiment will not ſucceed with that of every perſon) the letters appearing, upon rubbing thereon the black aſhes of burnt paper. A confection, made up with the pulp of ſloes, accidentally ſtaining a large quantity of new damaſk, from the top to the bottom, by ſteeping it, for ſome hours, in new milk, and, afterwards, cauſing it to be carefully waſh'd in more of the ſame; the damaſk came out unſtain'd and white. Urine will, uſually, take ſtains, even thoſe made by ink, out of linen; and with ſtrong ſpirit of ſalt I have done the ſame; firſt wetting the ſpotted places with fair water, whence, after waſhing, no iron-mole has remain'd. Some ingenious perſons who deal much in *Lixivia*, and brines, complaining of inconveniencies that attend the trial of the ſtrength of ſaline liquors, by means of an egg; for, to mention no others, the ſame egg will, by being kept, grow lighter, and, therefore, when ſtale, they have, uſually, a large cavity at the bigger end; I recommended to them the uſe of a piece of amber, for that purpoſe, of what magnitude beſt ſuited their occaſions. Being once in a place where I cou'd not procure ſome *Dantzick* vitriol, that I wanted; and obtaining, therefore, ſome liquor which the rain had waſh'd from green vitriol, or copperas-ſtones, and, adding thereto a proper quantity of copper, I made it ſerve as a menſtruum to work upon the metal; and by exhaling the ſolution, obtain'd the blue vitriol I wanted. And the like, I doubt not, may be done with all thoſe common green vitriols made of iron, wherein the ſaline part is not too much ſatiated with the ferruginous. A great dealer in cyder expreſſing a deſire to be able to make that liquor ſtronger, ſo as to keep longer than ordinary; I told him, to infuſe, for twenty-four hours, in ten or twelve

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gallons of the juice of apples, about two buſhels of the ſame kind of fruit, groſly bruiſed; then, gently preſſing them, to repeat the infuſion; obſerving not to make it too thick: and this ſucceeded excellently. Searching accidentally in a dark place, where ſtood ſome chymical glaſſes, I knew nothing of, negligently ſtopped, and not wrote upon; one happen'd to fall, and grievouſly ſtain a new ſuit I had on: but judging, from the nature of the ſtain, that it proceeded from ſome acid ſpirit; by ſearching about, and ſmelling to the remaining bottles, I found one that I gueſs'd, by its ſcent, to abound with volatile ſalt; and with this liquor I bath'd the ſtain'd parts, which immediately reſtored them to their former colour. By the like means, alſo, I have preſently remedied the diſcolourations made in garments, by fretting liquors; which wou'd, otherwiſe, have been thereby render'd unfit for wearing. Diſcourſing, lately, with a ſtates-man, of the means whereby well-meaning perſons may be injured and defamed, I ſaid, there was a way to take clear out of a parchment-writing all the words it contain'd, ſo that one might, by leaving the name, ſubſtitute what one pleas'd. And to ſatisfy him hereof, I did, in a few minutes, take off from parchment all that was written thereon; without defacing the parchment. Some attempt to do this on paper with *Aqua-fortis*; but that, by diſcolouring the paper, gives a ſuſpicion of the trick. But, as for the perfect way of performing this experiment, with others of the like nature, which I have ſometimes, out of curioſity, ſucceſsfully made; I think it much fitter to conceal than to communicate them; becauſe, ſhou'd they fall into the hands of perſons inclined to miſapply them, they might greatly diſturb human ſociety. A virtuoſo, having made a ſolution of gold, ſuſpected the metal alloy'd with copper, and therefore unfit for his purpoſe; I adviſed him to precipitate the gold by an urinous ſpirit, which it did, into a fine calx, while the fluid, remaining highly tinged with blue, betray'd the copper that had been uſed as alloy.

Theſe trifling inſtances being more pertinent to my deſign, than others, in themſelves of greater value, is the reaſon I have choſe them; nor ſhall I repent the mention of them, if they ſerve to ſhew, that the meaneſt experiments may ſometimes be uſeful, and better adapted to convince ſtrangers to philoſophy of its numerous uſes, than thoſe of a higher and abſtruſer nature. As, to know the uſe of a bladder of air, may be more ſerviceable to a pilot in a ſhipwreck, than the moſt hidden properties of the magnet; ſo, in ſome caſes, obvious and ſlight experiments prove vaſtly more welcome and uſeful, than more conſiderable ones wou'd at another time: ſo true it is, that "every thing is "beautiful in its ſeaſon." For my part, I cannot but hope, that natural philoſophy will prove daily more ſerviceable both to particular perſons, and trades themſelves; eſpecially if a farther enquiry be made, and thereby new qualities detected, and unheeded uſes of natural and artificial philoſophy diſcover'd. For whoever narrowly conſiders it, will find, that trades, at preſent, deal with but very few of nature's productions, in compariſon of thoſe they leave unemploy'd; and that, what they do make uſe of therein, are their obvious qualities, bating ſome few more ſecret properties which chance, or a lucky ſagacity, rather than ſkill and enquiry, have diſcover'd; and, therefore,

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I ſcruple not to aſſert, that if men were thoroughly ſenſible of their own intereſt, and wou'd carefully keep their eyes open upon the properties of things, and the application that might be made thereof, in human life; they might not only diſcover new qualities thereby, and ſo produce new trades, but even convert them to ſuch uſes as the inventor little imagin'd: and of this I might produce various inſtances.

To theſe general conſiderations, I muſt add, with regard to the following, that the reader is not to expect a methodical enumeration of all the grounds and motives I have to expect great advantages from a future progreſs in the knowledge of nature, for I chooſe to confine myſelf to what I can render probable by examples, and inſtances of that which is already acquired, or, very likely, ſoon will be. It muſt not, therefore, be imagin'd, that I have overlook'd all the particulars pertinent to my ſubjects; nor that I propos'd to ſet down all the inducements that might be brought to ſhew the uſefulneſs of experimental philoſophy. My deſign is only to render the expectations of advantages to be receiv'd from it probable; to do which, is taking a good ſtep towards the attainment of the things themſelves, as Sir *Francis Bacon* well obſerves. And I, the rather, endeavour to heighten mens expectations herein, becauſe many there are, who, being bred up in the vulgar barren philoſophy, judge of all philoſophy by that; and becauſe ſome moroſe authors, and deſpondent perſons, who have unſucceſsfully attempted to perform things deliver'd by unfaithful writers, fancy, and wou'd perſuade others, that nothing conſiderable is performable by natural philoſophy; our forefathers having, if we credit theſe perſons, had the good luck to hit upon all the profitable inventions which philoſophy can afford mankind. It may here, alſo, poſſibly be expected that I ſhou'd treat particularly of the principal means whereby a naturaliſt might advance trades, and aſſiſt mankind to recover part of his loſt empire over the works of nature. And I confeſs I have had thoughts of a project to advance experimental philoſophy, conſiſting of ſuch heads as theſe. A proſpect of what may probably be attain'd to by philoſophy, both in theory and practice. A brief account of what is already obtain'd thereby. The imperfection of our preſent attainments. What helps we now enjoy. The inſufficiency of our preſent helps. The hindrances and cauſes of them. And, laſtly, the means and helps that may be applied. But I did not here propoſe a juſt treatiſe; only to regiſter ſome looſe and ſcatter'd experiments and obſervations.

SECT. II.

The uſefulneſs of mathematics to philoſophy.

WERE it allowable for none but great mathematicians to diſcourſe of mathematics, I might be accuſed of preſumption to engage in it; for the authority of ſome famous modern naturaliſts prevented my making any extraordinary progreſs in that ſtudy, by abſolutely denying it to be uſeful in philoſophy. But a knowledge far inferior to that of *Archimedes*, or *Apollonius*, may ſerve to ſhew the advantages of mathematics in the contemplation of nature. Leſt others, therefore, ſhou'd be influenced by the like authorities, I ſhall enter a little into this ſubject. I know the extravagant opinions of *Kepler*, and other great mathematicians, are pleaded againſt the uſefulneſs of mathematics in natural philoſophy;

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loſophy; yet, from reflecting upon ſeveral mechanical experiments, I diſcover'd how ſerviceable it might be made thereto: and, therefore, I have often wiſhed, I had employ'd upon the theory moſt of that time I ſpent in the practical part of this ſcience. For a competent knowledge in mathematics is ſo neceſſary to a philoſopher, that I ſcruple not to aſſert, greater things are ſtill to be expected from phyſics, becauſe thoſe who paſs for naturaliſts, have been generally ignorant in that ſtudy. Now, mathematics may be, particularly, aſſiſting to philoſophy in many reſpects beſides thoſe general advantages which they bring to the minds of men, whatever be the ſtudies whereto they addict themſelves; and, conſequently, to the philoſopher*. For, in general, they make men accurate, and attentive to what they are about, by keeping their thoughts from wandering, and enuring them to patience in going thro' tedious and intricate demonſtrations; and thus they greatly improve the reaſon, by habituating it to deduce ſucceſſive conſequences, and judge thereof, without readily acquieſcing in any thing but demonſtration. But the operations in algebra ſeem to afford one of the cleareſt exerciſes of reaſon; nothing being therein performable without ſtrict and watchful reaſoning; whilſt the whole method, and the ſeveral ſteps, appear at one view, when the operation is finiſh'd. Before I deſcend to the particular uſes of mathematics in natural philoſophy, let it be obſerved, firſt, that the phenome a which the mathematician concurs to exhibit, really come under the cognizance of the naturaliſt; for when matter is endow'd with qualities, the conſideration how it came by them relates rather to the agent or efficient, than to the nature of the body itſelf. Thus the image made by a mirror, tho' that be an artificial body, falls under the conſideration of the naturaliſt, as well as when the like image is preſented by calm and clear water; and artificial rain-bows have as juſt a title to his contemplation, as that form'd in the clouds. The ſame may be ſaid of echoes. And, indeed, ſuch kind of phenomena uſually require the ſame ſolutions, whether human ſkill intervene or no, in their exhibition. And ſecondly, that, as we formerly ſaid, man's power over the creatures depends chiefly on his knowledge of them; and therefore whatever ſerves to encreaſe his knowledge, is likely to encreaſe his power. Theſe two obſervations being premiſed, I come to particulars.

In improving the mind.

Teaching the figures of bodies.

Mathematics, then, teach men the nature and properties of figures, both in ſurfaces and ſolids, with the relation between the ſuperficies and ſolidity of the ſame body. Matter is, indeed, the ſubject of the naturaliſt's ſpeculations; but if all the operations thereof depend upon the modifications its local motion receives from the magnitude and figure of its parts, it cannot be doubted, but the knowledge of what figures are more or leſs capacious, more or leſs proper for motion, penetration, reſiſtance, *&c.* muſt be of conſiderable uſe in explaining many phenomena of nature: but the doctrine of figures is wholly learnt from the geometricians, who treat expreſly of triangles, circles, ellipſes, parabolas, hyperbolas, ſpheres, cones, cylinders, priſms, pyramids, cubes, *&c.* and thereby intimate the figures of other bodies compoſed hereof, or bearing ſome analogy to them. There are various

* Nothing can more powerfully recommend the ſtudy of mathematics, than to know, that the grand diſcoveries of Sir *Iſaac Newton*, are made by means thereof; and were without that aſſiſtance impoſſible.

properties

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properties both of plain and ſolid figures, with their relations, particularly ſuch wherein motions are made, the knowledge whereof may be of great uſe both to the ſpeculative and practical naturaliſt. To know the proportion which *Archimedes* has demonſtrated between a ſphere and a cylinder; of both theſe to a cone; that a pyramid is the third of a priſm with the ſame baſe and altitude; in a word, to know the proportions between the geometrical bodies, may be uſeful in caſes where one, and not another of them, is procurable. We have an inſtance hereof from *Ghetaldus*, who cou'd not procure an exact metalline ſphere, wherewith to examine the proportionable weight of bodies of the ſame bulk; and therefore, in its ſtead, made uſe of a true cylinder, which was eaſily attainable; having learnt from *Archimedes*, that a cylinder, whoſe baſe equals a great circle of a ſphere, and height, the diameter of the ſame, is to that ſphere as three to two; ſubſtracting, therefore, a third part of the whole weight of his cylinder, the remainder gave him the weight of the ſphere he deſired: and this being once obtain'd, he thence deduced the weight of other ſpheres he had occaſion to employ, in the conſtruction of thoſe tables, that have been greatly uſed by ſucceeding mathematicians. And I myſelf have, alſo, made applications of this ſame theorem of *Archimedes*. Since *Galilæo* and *Torricelli* have demonſtrated, that projectils, in their motion, deſcribe a parabola; it muſt be of ſervice in the art of gunnery, and other caſes, to be well acquainted with the properties of that figure; which is, alſo, thought capable of performing wonders in *Specula*, cou'd they be ground thereto: for all the rays of light, falling then parallel to the axis, they wou'd be reflected from the ſurface, to a point, or focus; where, if the glaſs, or metal, be large, the heat will be more intenſe, than from a ſpherical glaſs of equal magnitude. But I ſhall not, here, inſiſt upon the numerous diverting experiments to be made in catoptrics, by means of ſpherical, cylindrical, and other kinds of reflecting glaſſes.

Even pure mathematics, excluſive of the advantage it brings to the mixt, may be greatly uſeful in human life, and to experimental philoſophy. The properties of arithmetical and geometrical progreſſions, in numbers, ſeem foreign to the buſineſs of ſhops and ware-houſes; yet, by a knowledge of the double progreſſion, beginning with an unit, as, 1, 2, 4, 8. wherein the conſequent is always double to the antecedent, much trouble and expence may thereby be ſaved; for, with three weights, all the pounds from one to ſeven, incluſive, may be weigh'd; and with four, all thoſe not exceeding fifteen: and from this obſervation proceeds the diviſion of ſome ſets of weights uſed by our goldſmiths. But if weights are to be uſed in both ſcales, to reduce them to an equilibrium; the triple progreſſion, as, 1, 3, 9. has a more notable property, from the conſideration whereof, *Stifelius* concluded, that, by three weights, any number of pounds may be weigh'd, from one to thirteen, incluſive; with four, any number from one to forty, incluſive; with five, any not exceeding a hundred and twenty-one; and with only ſix weights, all the pounds from one to three hundred and ſixty four. But the method of ordering ſo few weights, to ſerve ſo many purpoſes, is beſt found out by algebra; and being as well applicable to the parts of pounds of different denominations, it may be ſerviceable to thoſe who make ſtatical experiments. The *Regula combinatoria*, likewiſe, tho' not fully explain'd

Dividing of weights.

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plain'd by the modern algebraiſts, will, if I miſtake not, when ſymbolically managed, and ſkilfully applied, be very ſerviceable to the naturaliſt, on certain occaſions.

In framing hypotheſes. We may next obſerve, that mathematics will greatly aſſiſt the naturaliſt in framing hypotheſes, and judging of thoſe advanced by others. What wretched theories even famous naturaliſts may run into for want of this knowledge, appears from the accounts which *Epicurus* and *Lucretius* give us of the celeſtial bodies. And, indeed, what ſatisfactory account can be given of the varying lengths and viciſſitudes of days and nights, eclipſes, the ſtations and retrogradations of the planets, and other aſtronomical phenomena, without mathematical knowledge? And without the doctrine of the ſphere, what naturaliſt can tell, which is the true ſyſtem of the world, the *Ptolemaic*, *Tychonic*, or *Copernican*? Without arithmetic and geometry no knowledge can be had in aſtronomy, eſpecially not of the intricate theories of the planets; yet this ſcience cannot be too highly prized, that tells us our earth is but as a center to the immenſely diſtant ſphere of the fixed ſtars.

Shewing the true ſyſtem of the world. The uſefulneſs of pure mathematics to geography is evident; and, ſurely, no inquiſitive perſon will deſpiſe arts, which, alone, can ſhew us, whether the earth we inhabit moves, or ſtands ſtill. But there are various phenomena of nature, neither aſtronomical, nor geographical, wherein the uſefulneſs of mathematics is viſible; for, as to phenomena of viſion, what a pitiful account have we of it from the *Ariſtotelian* philoſophers, phyſicians, and even famous anatomiſts, who were ſtrangers to geometry, in compariſon of the modern mathematicians? And whoever is acquainted with dioptrcis, muſt be ſenſible, that a knowledge of the properties of convex bodies, the laws of refraction, and the doctrine of conic ſections, are required to explain moſt of the phenomena in viſion. A ſtranger to this part of mathematics will ſcarce underſtand the admirable ſtructure of the eye; how the cryſtalline humour refracts and converges the rays of light that come from the object, to paint the picture, upon the *Retina*, in the bottom of the eye; why that picture, by reaſon of the croſſing of the rays, is there inverted, tho' the objects themſelves appear erect; why ſmall objects, placed near the eye, and ſeen under a greater angle, ſeem as large as bigger, that are more remote therefrom; and much leſs will he comprehend the reaſon of many deluſive appearances exhibited by concave, convex, conical, and cylindrical glaſſes.

The laws of optics.

The doctrine of ratio's. And ſince from the magnitudes of different bodies, or the various parts of the ſame, and their degrees of velocity in motion, a certain relation will ariſe, called *ratio*, or proportion, the doctrine whereof is the nobleſt part of mathematics; he, who is not indifferently ſkill'd in this ſcience, has laid but a poor foundation for philoſophy. The fifth book of *Euclid*'s *Elements*, where the doctrine of proportions is principally deliver'd, may, perhaps, prove more inſtructive to a naturaliſt, than the fifth book of *Ariſtotle*'s phyſics. No wonder, then, that *Plato*, by an inſcription placed over the gate of his ſchool, forbid entrance to thoſe unſkill'd in geometry; as being unfit to judge of what he taught. Nay, there are ſome conſiderable phenomena of nature, which will remain unintelligible to thoſe who know nothing of the doctrine of proportions. Thus, when 'tis ſaid, in optics, that light decreaſes, in a duplicate proportion of its diſtance from the illumin'd body, a perſon unacquainted with proportions cannot affix any meaning to this theorem; much leſs cou'd he know the truth thereof. So when the ſame pro-

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propoſition is by *Merſennus* applied to ſounds, a common reader wou'd remain in the dark, did not the author add, by way of explanation, that if, for inſtance, the ſound of a piece of ordinance be heard at a league's diſtance, the ſaid ſound wou'd be heard four times ſtronger at the diſtance of half a league. Nor will this example itſelf give ſuch a reader, as we ſpeak of, a clear idea of the propoſition. We have a more conſiderable inſtance of this kind from the noble diſcovery made by *Galilæo*, that when a heavy body deſcends in the air, the ſpaces thro' which it paſſes, are, from the beginning to the end of its fall, in a duplicate ratio of the equal parts of time ſpent in falling; for he obſerved, that a braſs bullet, of an hundred pound weight, deſcended, in the ſpace of one minute, an hundred *Florentine* cubits, or one hundred and eighty *Engliſh* feet; but then it falls in ſuch a ratio, that it's velocity encreaſes in a progreſſion of odd numbers, beginning from an unit; ſo that if in the firſt moment the weight fall one fathom; in the ſecond, it will fall three; in the third, five; in the fourth, ſeven, *&c.* whence *Merſennus* gives this general rule: "if the times be given to find the "ſpaces, ſquare the former, and you'll have the ratios of the latter; but if the "ſpaces be given to find the times, the root of the ſpaces will give the ratio "of the times." Another inſtance, to ſhew the uſe of mathematics to a naturaliſt, may be taken from ſtatics, where, in the balance or lever, the proportion between equivalent weights, and their diſtances from the prop, is reciprocal; whence, with the ſtilyard and a ſingle weight, a conſiderable number of pounds may be weigh'd. But this grand theorem with others, that alſo ſerve to explain the phenomena of motion, cannot well be underſtood without an inſight into geometry, and the doctrine of proportions. And that mechanics may vaſtly aſſiſt the naturaliſt, will be readily allow'd, when 'tis known how many of nature's works are engines, and operate accordingly.

The doctrine of proportions, as it is the ſoul of mathematics, ſo it may become prodigiouſly ſerviceable in philoſophy alſo; and that not only by aſſiſting the naturaliſt to underſtand, as we have ſeen, many phenomena of nature, but as it may enable him to perform what he otherwiſe cou'd not. The pendulum is the moſt accurate inſtrument we, at preſent, have for meaſuring ſhort ſpaces of time; but he who wou'd know the due length of one to ſwing any determinate ſpace, as half a ſecond, for inſtance, muſt find it out by trial and obſervation, unleſs he be acquainted with the doctrine of proportions; whereas, if that be underſtood, and the phenomena of pendulums, he may, from the length of one that meaſures a known part of time, deduce the length of others to meaſure different parts thereof; without making any new trials or obſervations. Thus, according to *Merſennus*, a ſtring, with a bullet fixed to the end of it, the length whereof, including the bullet, is three feet and a half, vibrates ſeconds*; and it is a known theorem, that "pendulums, alike in every thing but length, have "their lengths in a duplicate proportion of their reſpective times of vibration, "or as the ſquares of their vibrations in the ſame time;" whence the times are in a ſubduplicate proportion to the lengths of the pendulum: if a pendulum,

* According to *M. Huygens*, the length of the pendulum that vibrates ſeconds is 3 *French* feet. 8 ½ lines. *Horolog. Oſcillator.* Part. 4. prop. 25. Or, according to common uſe, among us 39, 2 inches.

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therefore, were deſired to vibrate half ſeconds, it muſt not be a foot and three quarters long, which is half the length of one that vibrates whole ſeconds; for that wou'd be much too long; nor cou'd it ſometimes, for want of a ſtandard, be diſcover'd how great the exceſs was: but as the proportion between a ſecond and half ſecond is double, and the proportion between the length of the two ſtrings muſt be duplicate of that of the times; it follows, that the length of the ſtrings muſt be, as 4 to 1, which is duplicate of 2 to 1; ſo that the ſtring, to vibrate ſeconds, ought to be but a fourth of the length of the other. And this appears from other calculations, and experience itſelf.

The art of compoſing the vaſt variety of tunes that render muſic ſo delightful, depends upon the doctrine of proportions; and whoever is well ſkill'd herein, and can apply it to notes or words propoſed, according to the obſervations of the gratefulneſs of particular conſonancies, may of himſelf compoſe a great variety of new and pleaſing tunes, which are ſo many inſtances of his power.

Mathematics may ſuggeſt new experiments.

Perhaps, alſo, mathematics may ſuggeſt to the naturaliſt many new experiments whereby to vary thoſe already made concerning the figures of bodies, the lines of motion, numbers, proportions, and the like; for 'tis probable, that ſuggeſted experiments as wou'd either be overlook'd, or unſkilfully propoſed, for want of mathematics, will either immediately, or by means of their applications, prove ſerviceable to mankind. What numbers of experiments and obſervations in the deſtructive art of gunnery have been propoſed and made from hints ſuggeſted by mathematicians?* But theſe I leave, and come to their leſs pernicious diſcoveries. Pure mathematics have help'd to diſcover, and derive from familiar obſervations, a great variety of phenomena. From obſerving, that the rays of light are refracted in paſſing thro' different mediums; and that, in particular circumſtances, the ſun and moon will be eclipſed at particular times, very conſiderable deductions have been made by mathematicians in optics, aſtronomy, geography, navigation, and chronology. And whoever conſiders the doctrine of proportions, of concords and diſcords, with the great number of muſical inſtruments they have occaſion'd, and the other kinds of hints they may afford; and is, at the ſame time, acquainted with thoſe ingenious and uſeful experiments in optics, derived from obſerving that the angle of incidence made by the rays, is equal to that of reflection; that on curve ſurfaces the angle may be eſtimated as made by a tangent thereto; that the rays paſſing from a rarer medium into a denſer, are refracted towards the perpendicular; but, out of a denſer into a rarer, from the perpendicular; whoever, I ſay, conſiders all this, and how great a variety of propoſitions have, by the mathematics, been deduced from theſe few obſervations, cannot but grant what, by ſo many inſtances, I have endeavour'd to prove†. To conclude this ſubject; many practical points of doctrine reckon'd among mixt mathematics, may aſſiſt the naturaliſt in making experiments and obſervations, which he cou'd either not at all, or but imperfectly, make without them; thus,

* For a complete theory of the whole art of gunnery, deliver'd in a few propoſitions, ſee *Philoſ. Tranſ.* N°. 179. p. 9. Or, rather, the poſthumous works of Mr. *Cotes*, lately publiſhed by his worthy ſucceſſor in the *Plumian* chair.

† Upon theſe, and a few other properties of light, demonſtrated by others, and taken for granted by Sir *Iſaac Newton*, that great philoſopher, has raiſed his wonderful theory of light and colours.

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dialling, for inſtance, teaches to meaſure time, and tends chiefly to practice; the art of perſpective is of great ſervice in repreſenting ſolids and diſtances upon ſmall and plain ſurfaces; as alſo in limning: and with this both ſcholars and travellers wou'd do well to acquaint themſelves, in order to repreſent and adorn the hiſtory of nature, and ſeveral parts of navigation. But if it be undeniable, that in theſe, and other inſtances, mixt mathematics are of uſe to the naturaliſt, and enable him to extend the empire of mankind; 'tis certain, that pure mathematics muſt be ſo too; ſince 'tis from the theory, that not only theſe more practical parts are derived, but a greater number of mixt mathematical ſciences may take their riſe. Muſic conſiſts of pure mathematics and ſounds, hydroſtatics of mathematics and water; ſo that by an union thereof, with other ſubjects, the doctrines of mixt mathematics will probably be advanced, both in number and uſefulneſs. Nor is it only upon the foreſaid parts of learning wherein uſeful applications of pure mathematics may be made: other ſciences have a great dependance on theſe ſublime ones, and particularly thoſe which, in a large ſenſe, are call'd mechanical, whereof we come next to treat.

SECT. III.

BY mechanics, I underſtand not ſimply the doctrine of the moving powers, or the method of improving force, and forming engines; but in general, all thoſe parts of knowledge that conſiſt in the application of pure mathematics to produce or modify motion in bodies*. That this ſcience, therefore, is

Mechanics advantagious to natural philoſophy.

* 'Tis a juſt notion of mechanics which Sir *Iſaac Newton* delivers in the preface to his admirable *Principia*. "The ancients," ſays that great author, "made two kinds of mechanics, "a rational and a practical. For the manual "operator, uſually performing his part inaccurately, gave occaſion to diſtinguiſh between "mechanics and geometry, and ſo to refer "whatever is perfect to the latter; but what "is leſs perfect, to the former. The error, "however, is not owing to the art, but thoſe "who practiſe it. Whoever works inaccurately, "is an imperfect mechanic; but cou'd a man "perform to the utmoſt exactneſs, he wou'd be "a perfect mechanic. To deſcribe right lines "and circles, in which geometry is founded, "belongs to mechanics; and geometry does "not teach to draw them, but ſuppoſes them "to be drawn; for it requires that the ſtudent "ſhou'd exactly deſcribe them before he enters "upon geometry; and afterwards ſhews how "problems may be ſolved by means of theſe "operations. To deſcribe right lines and circles are problems, but not geometrical ones; "the ſolution of them being ſuppoſed from mechanics, and their uſe, when ſolved, taught "in geometry. ——— Geometry, therefore, is "founded in the practice of mechanics, and is "only that part of univerſal mechanics, which "with accuracy propoſes and demonſtrates the "art of menſuration. But manual arts being "principally employ'd in giving motion to bodies, geometry is commonly confin'd to magnitude, and mechanics to motion. And in "this ſenſe rational mechanics is an accurate "exhibition and demonſtration of the doctrine "of motions, from whatever powers they proceed, and of the powers neceſſary to all motion."

"The effects of machines," ſays that excellent mathematician *C. Wolfius*, "following up"on their ſtructure by unalterable laws of nature, all operations of bodies are call'd mechanical, becauſe they act agreeably to their "ſtructure, and the eternal laws of motion. He, "therefore, is a mechanical philoſopher, who "plainly ſhews, by the laws of motion, how "the effects of things follow from their ſtructure." *Wolfii Element. Mechan.* p. 642.

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greatly advantagious to experimental philoſophy, and to enlarge the empire of man, appears, in that many of thoſe things above ſhewn to render mathematics uſeful to the naturaliſt, may, *mutatis mutandis*, be underſtood here alſo; tho' this ſcience has ſome peculiar advantages. To come to particulars. The phenomena of this doctrine belong to the hiſtory of nature in its full extent, and therefore challenge the naturaliſt's conſideration; ſo that being thoroughly underſtood, we may well ſuppoſe it will greatly contribute to the advancement of his knowledge, and conſequently of his power. Thus, for inſtance, when a piece of wood plunged in water emerges and floats, even vulgar naturaliſts think it belongs to them to account for this phenomenon, which they fancy proceeds from the poſitive levity of the wood; tho' ſome woods that ſwim in water, may ſink in oil or ſpirit of wine. And may not a philoſopher find out the reaſon, why one part of floating wood keeps above the ſurface, whilſt the other ſinks beneath it; and why the extant part of different kinds of wood bears different proportions to that immerſed, in the ſame or different waters? For if theſe, and the like phenomena, be carefully examin'd hydroſtatically, the cauſe thereof will not only appear; but alſo, by applying that diſcovery, an eaſy way is obtainable to eſtimate the different ſtrengths of ſalt-ſprings, brines, and lixiviums, with other practical corollaries.

By helping to invent and judge of hypotheſes.

Mechanics, alſo, help to invent, and judge of hypotheſes relating to the ſubjects wherein they are concern'd. This appears not only in the ſcrew, the crane, the balance, &c. but in many familiar phenomena, wherein this doctrine is uſually thought little concern'd; as the bearing a pike, a muſquet, on the ſhoulder; the force of a ſtroke given with a long or a ſhort inſtrument, or held in a particular poſture; the power of a ſhip's rudder; the rowing of boats; the breaking of wood; with a multitude of other common and obvious inſtances, whereof mechanics will furniſh us with a better account than the ſchoolmen, and ſuch as are ignorant of the properties of the centre of gravity, the ſeveral kinds of levers, the wedge, &c.

And ſolve phenomena; as particularly, in hydroſtatics.

But there are many things in phyſics that cannot be well explain'd, nor underſtood, without the aſſiſtance of mechanics; for, abundance of phenomena, the phyſical cauſes whereof may be aſſign'd by the naturaliſt, cannot be juſtly and properly deliver'd without a knowledge in ſtatics, hydroſtatics, &c. as appears by the above-mention'd examples of the floating and ſinking of wood in water; for, were the reaſon of this appearance demanded of a ſchool-philoſopher, he wou'd anſwer, that wood, abounding with air, an element much lighter than water, that detains it upon the ſurface of the fluid. But this reaſon is not ſatisfactory to a naturaliſt verſed in hydroſtatics. For, not now to examine whether there be ſuch a thing as poſitive levity, or whether the air poſſeſſes that quality, experience ſhews, that tho' when wood is lighter than an equal bulk of water, it will ſwim; yet if it be heavier, it ſinks therein; as guaiacum, wherein I the rather chuſe to inſtance, becauſe the chymiſts obſerve it leaves leſs aſhes (in which the terreſtrial and heavy parts are ſuppoſed to reſide) when burnt, than other woods which float on water. Iron and ſtones, by reaſon of their weight, are thought to contain little air, yet they riſe or float if immerſed, or plunged in a fluid ſpecifically heavier than themſelves; as any one may try with quick-ſilver or melt-

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ed lead; from whence it appears, that the predominancy of the air need not be regarded in bodies, when conſider'd as to their ſinking or ſwimming in a propoſed fluid. And tho' air were admitted as the cauſe of a body's floating, it cou'd only be a remote one; the immediate cauſe being, that the body is lighter than an equal bulk of the fluid; and, therefore, the ſame body, without acquiring or loſing air, may ſwim in one water, and ſink in another; as loaded ſhips have been found to do upon coming into freſh water: and an egg that ſinks in common water, will be ſuſtain'd in ſtrong brine. Nay, a body may be ſo poiſed, as to ſink if the fluid grow warm, and emerge again when that becomes cold. But if the levity of the air cannot account for the floating and ſinking of wood, much leſs will it afford a ſatisfactory reaſon, why different kinds of wood, in the ſame water, or the ſame kind in different waters, will ſink to a certain depth, whilſt this phenomenon is eaſily ſolved from hydroſtatics; for, according to *Archimedes*, "ſolids lighter than the fluid they are put in, "will ſink, till a quantity of the fluid equal in bulk to the part immerſed, "becomes equal in weight to the whole floating body;" from whence flow theſe corollaries. A floating body bears the ſame proportion in weight, to a quantity of fluid equal to it, in bulk, as the immerſed part of the body bears to the whole of the ſame body. A quantity of fluid, equal in bulk to the whole body, has the ſame proportion, in weight, to the ſaid body, as the whole body has to the part below the ſurface of the fluid. And as theſe corollaries determine the proportion between the immerſed and extant part of the floating body, they ſuggeſt a way of contriving a ſmall and light floating inſtrument to meaſure the different gravities of ſeveral liquors. And hence, alſo, *Stevinus* ſhews, that if the part of a floating body immerſed in a fluid be known, together with the ſpecific gravity of that fluid, the weight of the whole ſolid, how large ſoever, may be determin'd. Thus, ſuppoſe the part of a ſhip lying under water be 100,000 cubic feet, and that each cubic foot of water weighs 70 pound, multiply 100,000 by 70, and the product, 7,000,000 gives the weight of the ſhip, and whatever is contain'd therein. Ask a mere ſchool-philoſopher, why ſucking-pumps will not raiſe water above the height of 40 feet; or why, when a proper quantity of water and quick-ſilver is poured into an inverted ſyphon, the ſurface of the water in one leg will riſe vaſtly higher than the ſurface of the quick-ſilver in the other; or, laſtly, why, tho' a piece of iron, and another of marble, be equiponderant in the air, the metal appears much heavier than the ſtone when the ſcales are plunged in water; and, I fear, he will hence receive more perplexity, than you ſatisfaction. It were eaſy to add a multitude of queries whereof a naturaliſt, ignorant in mechanics, cou'd give but a very poor ſolution; which yet the mechanic wou'd ſatisfactorily anſwer. And for proof hereof, I refer the ſchoolmen to *Ariſtotle*'s mechanical queſtions. But to ſhew, that ſome phyſico-mechanical phenomena are unintelligible without a knowledge in mechanics, I ſhall produce a conſiderable theorem in hydroſtatics, thought to be firſt deliver'd by *Merſennus*. "The ve- "locity wherewith water deſcends and runs from tubes of equal bores, but "unequal heights, is in a ſubduplicate ratio of their heights:" whence we have this corollary, that ſuch tubes are in a duplicate ratio of the velocity of the water that ſubſides in, and runs out of, them; ſo that to make one cylindrical tube

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tube of the ſame bore with another, run, in equal times, twice as much water as that other, the former muſt be four times the length of the latter.

Mechanics will aſſiſt to multiply experiments.

And as was ſaid of mathematics, ſo alſo mechanics will aſſiſt the naturaliſt to multiply experiments by the enquiries they will ſuggeſt, and the inferences and applications whereto they lead. Hereof we have a noble inſtance in the *Torricellian* experiment, wherein almoſt every year produces new diſcoveries. *Merſennus*, alſo, has ſupplied us with abundance of new propoſitions in baliſtics. But *Galilæo* affords us ſtill more noble examples, relating to the reſiſtance of bodies in breaking; the force required to break them; and the length whereat their own weight will do it; which he has reduced into an art. 'Twere needleſs to add farther particulars on this head, conſidering what a variety of uſeful propoſitions have been deduced, and are ſtill mechanically deducible, from that obſervation of *Archimedes*, "that a ſolid body weighs leſs in water, than "in air, by the weight of a quantity of water equal, in bulk, to that body." And that many mechanical theorems are fertile both in other propoſitions and uſeful applications, I may hereafter ſhew, by the uſes I my ſelf have made of this very propoſition, and its corollaries.

The peculiar uſes of mechanics, in centrobarrics.

As for the peculiar uſes of mechanics, they conſiſt in the making proper inſtruments and tools for experiments and obſervations; and of this we have a remarkable inſtance in the mariner's compaſs, whence the benefits of navigation are derived. *Baptiſta Porta*, and others, aſcribe the diſcovery of the needle's directive faculty to *Amalphi*, a *Neapolitan*; yet that author owns, that for want of our preſent contrivance, this lucky inventor uſed a piece of wood, or ſtraw, to keep his needle afloat; which was a very inconvenient ſhift: and had mechanics never ſupplied us with a way to poiſe the needle, ſo as to keep it horizontal, notwithſtanding the rolling motion of the ſhip, the effect of the load ſtone wou'd have continued very inſignificant to the diſtreſs'd pilot. 'Tis mechanics, alſo, that, by means of the centrobarric doctrine, has enabled us to make the dipping-needle; whoſe phenomena are very odd: and tho', as far as I have try'd, they ſeem very uncertain; yet it may very poſſibly happen, that farther obſervation will reduce them to ſome theory, productive of practical inferences*.

That centrobarrics may be of immediate uſe, will appear more credible, if, as writers of unſuſpected veracity aſſure us, a kind of lamp has been made, and poiſed ſo, that tho' rolled about like a bowl, the oil will not be ſpilt, nor the

* The dipping needle ſeems, ſince the time of Mr. *Boyle*, to have been applied to little elſe than the diſcovery of iron-mines; till Mr. *Whiſton* happen'd to conſider it, and attempted to apply it to a much more noble purpoſe; the diſcovery of the longitude at ſea. He obſerves, that if it be 6 inches radius, of a priſmatic or cylindrical figure, and oſcillates along the magnetic meridian, it here performs every mean oſcillation in about 6″, and every ſmall one in about 5″; but that if it be 4 feet long, it makes every mean oſcillation in about 24″, and every ſmall one in about 22″; that the force of magnetiſm in this country, as it affects needles of a foot in length, is to that of gravity, nearly as 1 to 300; that the quantity of magnetic power, accelerating the ſame dipping-needle, as it oſcillates in the ſame vertical plains, is as the co-ſines of the angles made by thoſe plains, and the magnetic meridian, taken on the horizon; and, that the times of oſcillation and vibration in dipping and horizontal needles, equally good, are as their lengths directly; and the actual velocity of their points along their arcs always equal. See *Whiſton's Dipping-Needle.*

flame

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flame extinguiſh'd. To remedy the inconveniencies of *Cardan's* lamp, I contrived one after the following manner.

ABCD, is a veſſel of latton, well ſolder'd every where. *Fig.* 1.

BC, *EF*, are two bottoms ſolder'd to that veſſel.

FG, is a pipe ſolder'd to the bottoms; and whoſe aperture is in the great cavity *FA*.

H, is a hole in the pipe *FG*, opening between the two bottoms, *BC*, *EF*.

I, is another hole, to which is ſolder'd a pipe *IG*, bent upwards, at *G*.

PP, is a little veſſel fit to receive the wieck of the lamp.

LM, is a ſlender pipe, open at both ends, and ſolder'd to the cover *AD*, in *L*; and to the bottom *EF*, in *M*. So that by this pipe the external air may communicate, between the two bottoms, without penetrating into the vity *AF*.

N, is a ſhort pipe, ſolder'd to a hole in the cover *AD*, whereby oil may be poured into the cavity *AF*, and that be ſtopp'd afterwards very cloſe with cork.

For the filling up of this engine, you muſt ſtop the aperture *G*, of the pipe *IG*, with a long pin fitted for that purpoſe; and the upper end of the pipe *LM*, muſt be ſtopp'd too; then pour in your oil by the aperture *N*; which done, the ſame aperture *N*, is to be ſhut up exactly, and both the other to be opened, *viz.* *G*, and *L*. Then the oil, through the pipe, *IG*, will run and fill the veſſel *P*, till its ſuperficies is in the ſame level with the hole *H*, and no more, as might be eaſily demonſtrated.

Now it is eaſy to ſee that this lamp is free from all the inconveniencies which the lamp of *Cardan* is ſubject to; for

1. The air doth not get into it by ſtarts or gluts, as it doth in *Cardan's* lamp; but when the oil in *PP*, being waſted by the flame, comes to have its ſuperficies lower than the hole *H*, the oil from the cavity *AF*, runs into *PP*, gently, becauſe its place left in the cavity *AF*, is eaſily ſupplied by the external air, which through the pipe *LM*, and the hole *H*, gets up into the ſaid cavity *AF*.

2. When the air contained in the cavity *AF*, comes to be rarify'd by ſome heat, it drives out much oil, and ſo is able to choak *Cardan's* lamp: but in this, the oil being thus driven out, gets into the ſpace between the two bottoms, as well as into the veſſel *PP*. Now the ſaid ſpace between the two bottoms, by reaſon of its largeneſs, receiving twenty or thirty times more oil than the veſſel *PP*; it follows, that the ſuperficies of the oil therein riſeth twenty or thirty times leſs than if all the oil had been driven into the ſaid veſſel. Therefore, when we fill the lamp, we muſt take care that the pipe *L*, be well ſhut, ſo that the air between the two bottoms, finding no iſſue, may keep the oil from filling that ſpace, which by this means, when the hole *L*, is open, will be fit to receive the oil driven out by the rarifaction of the air in the cavity *AF*.

3. The oil being always kept at the ſame diſtance from the flame, the wieck will not be quickly conſumed.

4. We here have the conveniency to put new oil into the lamp, without moving or extinguiſhing the ſame; for we need but ſhut up *G*, and *L*, and pour the oil through *N*, as was ſaid before.

From

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In the art of diving.

From knowing that compreſs'd air has a ſpring whereby it reſiſts farther compreſſion, and by a ſlight contrivance to apply this pneumatical principle, an acquaintance of mine made an engine, wherein he cou'd dive to the bottom of the ſea, and there continue ſometimes many hours, till wrecks, or things of value, were found, and cables tied to the ſunk guns of ſhips, which were afterward buoy'd up*. And by this means he acquired great riches.

And the uſe and application of valves, ſchemes, models, &c.

But ſo many examples might be given of mechanical inſtruments and tools uſeful to the naturaliſt, that it wou'd be tedious to enumerate them; nor is it neceſſary, ſince the ſhops, by exhibiting them, may well ſave us the labour. But as a knowledge in mechanics helps the naturaliſt to proper inventions, according to his ſeveral purpoſes, ſo one good contrivance may equal, and, perhaps, produce many uſeful experiments. He muſt certainly be a dull naturaliſt, who can know the properties of the centre of gravity, of levers, balances, ſcrews, wedges, *&c.* and, by frequenting the ſhops, have ſeen various engines to anſwer different deſigns, and not be able, by compounding, varying, and improving them, to deviſe means he wou'd otherwiſe not have thought on, to make new trials, or to repeat the old ones with more accuracy, eaſe, and ſome other advantages. And, that a good mechanical contrivance may be as valuable as many particular experiments, will appear from examples. To valves, tho' a ſlight and obvious invention, we owe not only a great variety of pumps, and bellows; but they alſo make very conſiderable parts of many other engines; and may, as ſome trials have inform'd me, be employ'd in ſeveral new experiments; eſpecially when made of braſs, and ſo ſmall, as ſome I have obtain'd from ſkilful workmen, that they may be uſed in little glaſs-pipes and ſyringes. By means of ſmall valves, and the knowledge of the ſpring of compreſs'd air, wind-guns have been contrived; which ſerve to ſhew the weight of the air, as well as to kill deer, or other game; without frighting away the reſt by any report.

Mathematics and mechanics too much confined in their application.

But, methinks, both mathematics and mechanics have been too much confind to the ſtars, the earth, the water, and ſome few conſpicuous parts of nature beſides; whilſt they might be extended by a philoſopher to various other productions, both of nature and art. Thus *Archimedes* deduced hydroſtatics from the application of vulgar ſtatics to the weighing of bodies in air and water, or water alone; and *Torricelli*, with others, lately applied the principles of hydroſtatics to quick-ſilver. But one conſiderable advantage both mathematics and mechanics may afford the naturaliſt, is, by ſchemes, figures, repreſentations, and models; which greatly aſſiſt the imagination to conceive many things, and by that means enable the underſtanding to judge of them, and deduce new conſequences therefrom. 'Twou'd be exceeding difficult, if not impoſſible, to go through ſome tedious geometrical demonſtrations without the help of a viſible ſcheme; not to mention how hard it is to initiate perſons in coſmography and geography without material figures and globes. And how neceſſary figures and models are in the building of ſhips, houſes, engines, and

* Dr. *Halley* has an excellent contrivance of a diving-bell upon this foundation; wherein he can, with all deſirable convenience, deſcend to any depth of the ſea, and there continue for ſeveral hours together. See a full deſcription of this engine, and the manner of uſing it, in the *Philoſophical Tranſactions*, No. 349. p. 491, and No 368. p. 177.

other

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other ſtructures, every one knows. And not only mechanics, mathematics, and anatomy, ſtand in need of ſchemes and repreſentations, to give clear conceptions; but many phyſical things may by the ſame means receive illuſtration. And if *Des Cartes* was the firſt introducer hereof, I think we are obliged to him; for, as *Plato* ſaid, God always acts geometrically; ſo, in many caſes, nature acts mechanically, in animals, plants, and many other bodies; the curious and fine contrivances wherein being well repreſented to the eye, may greatly aſſiſt us in framing juſt ideas of them.

SECT. IV.

Philoſophy beneficial, by being applied to trades.

I COME next to ſhew, that natural philoſophy, by adopting trades, may become very beneficial to mankind; for, firſt, a knowledge herein will improve the mind of a naturaliſt; and, ſecondly, enable him to advance them. 'Tis a prejudice no leſs pernicious than general, which natural philoſophy, and the intereſt of mankind, receive, that learned and ingenious perſons ſhould have been kept ſtrangers to the ſhops and practices of tradeſmen. Moſt of the phenomena that ariſe in trade, are a part of natural hiſtory; and, therefore, demand the naturaliſt's care. Nor will it excuſe the neglect and contempt of this part of natural hiſtory, in men of learning, that it muſt be learnt from illiterate mechanics; or, that the things it exhibits are works of art, and not of nature. The firſt plea is ſo unworthy of a philoſopher, as not to deſerve an anſwer; and as for the latter, there is not that difference men, uſually, imagine, between the productions of nature and art. Many things called artificial, differ not from the natural, in eſſence, but efficients: nature performs the greateſt ſhare of the buſineſs in abundance of trades; for inſtance, thoſe of the malſter, brewer, and baker; in preparing raiſins, currans, and other dried fruits; the making of hydromel, vinegar, lime, *&c.* for, in theſe, the tradeſman does but bring together the reſpective viſible bodies, and leave them to act on each other, according to their ſeveral natures. Thus, alſo, in making glaſs, the artificer puts ſand and aſhes together, but the diſſolution and union are brought about by the action of the fire thereon; as when it turns wood to aſhes, the volatile ſalt, oil, earth, and phlegm, unite firſt into ſmoke, and then into ſoot. When a pear is grafted on a white-thorn, the fruit it bears will ſcarce be thought unnatural, tho' produced by a coalition of two different bodies by means of human induſtry.

The phenomena of trades part of natural hiſtory, and to be learnt by a philoſopher.

But many phenomena in trades are, alſo, ſome of the more noble and uſeful parts of natural hiſtory; for they ſhew us nature in motion, and that too when turn'd out of her courſe by human power; which is the moſt inſtructive ſtate, wherein we can behold her. And, as the obſervations hereof tend, directly, to practice, ſo may they, alſo, afford much light to ſeveral theories; And theſe phenomena are, therefore, the fitter to be tranſlated into natural hiſtory,

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ſtory, becauſe the perſons, in whoſe hands they lie, uſually, know not how to deſcribe their own practices, or the accidents they meet with; ſo, that if learned men do not regiſter theſe things, the hiſtory of nature will be very defective. And, doubtleſs, a naturaliſt would manage theſe things in ſuch a manner, as to render them far more inſtructive, and ſuitable to the deſign of a natural hiſtory, than when related, tho' ever ſo faithfully, by an illiterate tradeſman. Now, certainly, he is unworthy the knowledge of nature, who ſcorns to converſe with the perſons from whom it may be beſt obtain'd. For tradeſmen are, commonly, more diligent, in their particular way, than any other experimenters would be, whoſe livelihood does not depend upon it. And, as neceſſity is the mother of invention, we, daily, ſee that this makes the neceſſitous crafts-man induſtrious and inventive; putting him upon employing ſuch things at he would, otherwiſe, never have dreamt of. By this means new properties, uſes, and applications of materials, are diſcover'd; and ſuch as have eſcaped the obſervation of others. Again, trades deal, not only in factitious, but natural materials, that are unknown to claſſical writers, and never uſed but in the ſhops; as manganeſe, zaffora, emery, tripoli, *&c.* and of both ſorts, there are ſome exceeding uſeful; thus glaſs-men and potters employ the two former, and a number of trades the two latter of theſe particulars. So, among artificial concretes, ſolders are neceſſary to gold-ſmiths, lock-ſmiths, copper-ſmiths, braziers, pewterers, tin-men, glaziers, *&c.* amels to gold-ſmiths, glaſs-men, *&c.* lakes to painters, heralds, *&c.* and putty to amel-founders, potters, ſtone-cutters, gold-ſmiths, glaſs-grinders, *&c.* And, even, of thoſe natural things, whereof mention is made in famous authors, many particulars may be learnt in the ſhops, not otherwiſe to be met with, as to their differences, characteriſtics of goodneſs, and the like. For my own part, I confeſs, I have learnt more of the kinds, diſtinctions, properties, and nature of ſtones, by converſing with two or three maſons and ſtone-cutters, than from *Pliny*, *Ariſtotle* and his commentators. Tradeſmen being unacquainted with books, and the theories and opinions of the ſchools, examine their materials by mechanical ways, which their own ſagacity, or caſual experiments affording them, may appear ſingular, and different from what learned men would have taught them; tho', if they ſerve their purpoſe, are new and inſtructive, and the rather claim a place in natural hiſtory. The obſervations of a tradeſman, may not, indeed, when firſt they make them, be ſo accurate as thoſe of learned perſons; yet, that defect is ſupplied by a frequent repetition and aſſiduity; ſo, that the circumſtances he paſſed over at one time, will obtrude upon him at another, till, at length, various phenomena will offer themſelves, even to an unattentive eye, which might have eſcaped a more curious perſon, in two or three experiments. Tradeſmen, moreover, frequently, remark, in the things they deal with, many circumſtances unobſerved by others, with regard to the nature of the materials, and the operations performable therewith. By goodneſs and badneſs, 'tis true, tradeſmen commonly mean the fitneſs, or unfitneſs of things, to yield a conſiderable price, in regard of the purpoſes whereto particular trades employ them; yet theſe properties uſually conſiſt in qualities relating to ſeveral other things, and applicable of ſeveral other purpoſes; for ſome of their *Criteria*, are a difference in the kinds of bodies, of the ſame denomination,

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nation. Thus, from the potter, the pipe-maker, and the glaſs-man, we may learn a great variety of clays; and no leſs an one of ſtones, unobſerved by claſſical writers, from ſtone-cutters and maſons. So from carpenters, joiners, and turners, we may learn, that ſome kinds of wood, as oak, will endure both wet and dry; that others will laſt well within doors, but not bear the weather; that ſome will hold good above ground, but not under water; and, laſtly, that others will continue better under water, than in the open air. And as the characteriſtics inform us of the differences in the kinds of bodies, ſo may they, likewiſe, of many qualities therein. Thus from the glaſs-men and ſoap-boilers, we learn that ſome aſhes, as thoſe of kali, bean-ſtalks, *&c.* abound much more in ſalt, and make clearer and better glaſs than others. The malſter teaches us the different impreſſions which barely receives from the fewel wherewith 'tis dry'd. And one whom I know, made great profit by preparing it with wood-fires, in ſuch a manner, that it could not be diſcovered ſo cheap fewel had been uſed therein; for he choſe and ſeaſon'd his wood, ſo that even the ſolid parts thereof, when cleft, burnt almoſt like ſtraw, with a clear flame ſurprizingly free from ſmoke. But farther, the naturaliſt, uſually, contenting himſelf to repeat his experiments, once or twice, at his leiſure, has not equal opportunities with the artificer, nor is ſo much intereſted to diſcern what influence the temper of the air, or the ſeaſon of the year, may have thereon. Thus tanners, we ſee, gather their bark in the ſpring, whilſt the riſing ſap abounds therein, becauſe it is not always ſo good for their purpoſe, nor parts ſo eaſily from the tree. Joyners think wainſcot not ſufficiently ſeaſon'd 'till it be many years old; and, butchers, in ſeveral countries, obſerve, that, tho' a bullock, under four or five years old, be good to eat ſoon after it is kill'd, yet, if ſalted, and kept long, 'twill thereby be fretted, and good for little. And, doubtleſs, 'tis a great advantage the naturaliſt may derive from trades, that the ſame things are, ſucceſſively, practis'd upon for many ages; whence more extenſive obſervations are made thereon, than a philoſopher has opportunity for. Thus thoſe who make mortars of *Guaiacum* wood, and deſign them to be good, will keep the ſtuff in the houſe for twenty years, or more, to ſeaſon, before they uſe it. And experienced maſons ſay, that ſome ſorts of lime and ſtone will decay in a few years, whilſt others arrive not to their full hardneſs in thirty or forty; of which I have ſeen inſtances. But a naturaliſt, by frequenting the ſhops of artificers, may, frequently learn other things, beſides the truth and falſity of what they relate, as to the hiſtory of their profeſſions; for he will there obſerve phenomena, that are neglected by the tradeſman, as impertinent, and not tending to his profit; while torturing nature by his art, he diſcovers to an attentive eye, things not to be met with in books, nor ever dreamt of by authors.

Who may thence improve them, various ways.

On the other hand, the naturaliſt, by his knowledge, gain'd from an inſpection into trades, as well as his other acquirements, may contribute to the improvement thereof. And this is performable ſeveral ways; but, particularly, by increaſing the number of trades; by collecting the obſervations and practices of different arts into a body; and, by ſuggeſting improvements in particular trades. Nor is it abſolutely requiſite to invent new ones, in order to increaſe the number of trades; ſince a revival of thoſe known to the ancients, that ſeem loſt to

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us, will ſuffice for this purpoſe; ſuch are the making of incombuſtible cloth of *Lapis Amianthus*, the *Tyrian* purple, and *Moſaic* work; with many others mention'd by *Pancirollus*, and his commentator *Salmuth*; of which it might be proper to divulge a catalogue; becauſe having been once, actually, in being, 'tis poſſible they may be retrieved in ſuch an inquiſitive age as the preſent. But trades may derive another advantage from the diligent naturaliſt, by means of ſeveral obſervations made, and different practices uſed, therein; which the artificers, themſelves, want either the curioſity, ſkill, or opportunities to learn: not to mention the jealouſy they have of one another, and their unwillingneſs to diſcover their ſecrets, where they think their intereſt concern'd; whilſt a philoſopher finds no ſhyneſs, who enquires only to ſatisfy his curioſity, or with a view to aſſiſt them. And, doubtleſs, were all the known hints, ſcatter'd thro' the various employments, poſſeſs'd by a ſingle perſon, tho' but of common abilities, he might thence improve moſt of the particular trades, that are retainers to philoſophy. And, perhaps, it were not amiſs, if ſome knowing, and experimenting perſons, were appointed by the public for this purpoſe. Some *French* gardeners have, lately, with good ſucceſs, applied the way of filtration, uſed by apothecaries, to water tender plants. They place wieks of cotton, or liſts of cloth, in the liquor to be ſtrain'd, ſo that they hang over the edge of the containing veſſel below either ſurface of the fluid. Theſe ends of the liſts, thus hanging over the roots of plants, will uniformly and leiſurely ſupply them with moiſture, far better than watering pots. And this method, by a cheap and mechanical contrivance, may be greatly improved. Stone-cutters, who caſt figures with plaiſter of *Paris*, have a way to obtain fine powders, beyond what the common ſearces would allow of, by ſtirring the pulverized material well in water, and, ſoon after, pouring off the turbid liquor, at the bottom whereof an impalpable powder will, in time, ſettle. Of this method I have made great uſe in chymiſtry. And if the firſt water be ſuffer'd to remain ſubſiding, 'till the finer parts begin to deſcend, a much more ſubtile powder may be gain'd, than that which artificers uſually employ. This method is, likewiſe, uſeful to glaſs-men, potters, the makers of teleſcopes and microſcopes, thoſe who caſt metals in ſand, and others; particularly in *China*, to the makers of porcellain. The naturaliſt may, alſo, render the materials of one trade ſerviceable to another. The philoſopher who has ſurvey'd a great number of arts, and compared them together, may well do this to advantage; ſince even illiterate mechanics themſelves can make uſe of each others productions. Thus litharge, which is only lead powder'd, and almoſt vitrified by being blown off the refiners teſt, not only ſerves the chymiſt for *Saccharum Saturni*, and the like medicines; but the comb-makers to dye their horn; being mixed with quick-lime and ſharp vinegar; painters, to accelerate the preparations of their fat oils; varniſhers, by cauſing their work to dry ſoon; and, laſtly, it ſerves to make counterfeit gems; for, by being melted with about a third part of pure white ſand, or calcin'd cryſtals, and then adding a ſmall quantity of mineral concretes, according to the colour intended, ſapphires, emeralds, *&c.* may be imitated; tho' they will come out too ponderous, ſoft, and dim the method itſelf, being

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not the moſt valuable. *Aqua fortis* is uſeful to refiners; for herewith they ſeparate ſilver from gold and copper; to the curious workers in wood, for ſtaining and diſcolouring thereof; to dyers, in their colours, and even in ſcarlet; and to other artiſts, for the colouring of bone and ivory; which they do by ſteeping them therein, when that is ting'd with copper, or verdigreaſe, *&c.* ſome, alſo, turn it into *Aqua regia*, by diſſolving in it a fourth of it's weight of ſal-armoniac, and then ſtain therewith ivory haſts and boxes, of a fine purple colour, that does not ſuddenly diſcloſe itſelf thereon. There are, moreover, book-binders, who throw it on leather, and thereby make fine marble covers for books; and diamond-cutters, who, therewith, free diamonds from metalline powders. 'Tis, farther, of great ſervice, in etching copper, or braſs-plates; and, laſtly, I have cauſed canes to be ſtain'd like tortoiſe-ſhell, by a mixture hereof, and oil of vitriol, laid on them at ſeveral times, over live coals, to cauſe it to penetrate the deeper; and, afterward, giving them a gloſs with a little ſoft wax and a dry cloth. Nor are theſe all the uſes made of *Aqua fortis*; which, tho' it be a liquor very commonly employ'd, and diſtilled not only by chymiſts, but refiners, gold-ſmiths, *&c.* yet great overſights are daily committed in its preparation. But an ingenious acquaintance of mine, by attempting to improve it, has ſucceeded ſo far as to make it vaſtly better than that the refiners uſually employ; or than any I have uſed; and, yet, he affords it for litttle more than half its common price. Nay, he has not only thus greatly promoted the refiner's trade, but found out a way to recover moſt of his *Aqua fortis*, after it has been employ'd in the ſeparation of metals, and that too with its virtue increaſed; for, this fluid may be made, and received in other veſſels than are uſual. And without dreaming of this chymiſt's method, I have re-obtain'd that menſtruum, exceeding ſtrong, after it had been employ'd upon certain minerals. Laſtly, there are other bodies, beſides glaſs and earth, and leſs brittle than they, that ſerve for the ſecond diſtillation of *Aqua fortis*, tho' made, originally, very ſtrong. I might, alſo, intimate, that, by adding to ſalt-petre, inſtead of thrice its weight of clay, or the like, about an eighth, or tenth of it's weight of another ſubſtance, I have, even in ordinary furnaces, ſlowly obtain'd a nitrous ſpirit, or *Aqua fortis*, at the firſt diſtillation, much ſtronger than what our refiners ſell for double *Aqua fortis*. Others have far greater opportunities to inquire into trades, than myſelf, yet I have, ſometimes, gain'd the thanks of eminent artificers for my directions in their reſpective trades and profeſſions*; which has made me often wiſh, that a few ingenious men, who are friends

* Thus M. *Homberg* inſtructs us how to gain a larger quantity of the eſſential oil of vegetables, than is uſual in diſtillation, by the previous addition of mineral acids, as the ſpirit of ſalt, *&c.* thereto; which increaſe the fermentation, and joining with the oil, render it more liquid, and eaſy to be raiſed by heat. This expert chymiſt adviſed a perfumer, who before ſcarce obtain'd an ounce of oil from a hundred weight of roſes, to ſteep his flowers, for fifteen days, in water made ſharp with ſpirit of vitriol, by which means the perfumer, upon diſtillation, found his quantity of oil increaſed almoſt a third. The perfumers keep the ſtructure of the veſſel they employ in this diſtillation as a grand ſecret. 'Tis a large convenient ſtill, that opens, in a tube, at the top, to receive the water which muſt often be pour'd upon the roſes, to bring over the oil with it; which it does but very ſlowly, and ſo requires that its quantity be large. This ſtill, alſo, opens below, that the flowers, when they will yield no more oil, may be, eaſily, taken out

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friends to experimental philoſophy, would enquire into the myſteries of trades, and, afterwards, publiſh the ſum of their obſervations, tending to the melioration thereof. Some *Italian* authors have wrote treatiſes of particular profeſſions, as *Antonio Neri* of the art of glaſs-making, and *Benvenuto Cellini* of ſculpture, ſtatuary, and ſome other arts; which deſerve to be made *Engliſh*.

And I invite the virtuoſi of all nations to contribute their obſervations towards forming the hiſtory of trades, for I eſteem that one of the beſt means to improve experimental philoſophy *. Of this I was ſo far perſuaded, that, had not our publick calamities prevented me, I ſhould have bound ſeveral ingenious youths to particular trades, with a view to receive, afterwards, their reſpective obſervations, made by my own direction, and the hiſtorical accounts of their profeſſions, when they ſhould have become maſters thereof.

There is, likewiſe, another means, whereby an experimental philoſopher may become advantagious to trades, I mean, by ſurveying the rules and obſervations already received, and the preſent reigning practices therein; then remarking the deficiencies and inconveniencies under which they labour, and noting their *Deſiderata*; and, laſtly, by propoſing rational means to remedy the former, and, as far as he is able to ſupply the latter. By deficiencies and inconveniencies, I don't here mean all that is wanting to ſuch an abſolute perfection, as a philoſopher might wiſh for; but what is complain'd of as feaſable to be remedied: as for inſtance, the artificer may be too much confin'd to particular materials, ſome whereof being either ſcarce, dear, or ill-condition'd, the naturaliſt might propoſe others. Thus, I remember, being once where no good vitriol could be procured, wherewith to make *Aqua-fortis*, like that of the *Engliſh* refiners; by ſubſtituting a far leſs quantity of burnt alum, in its ſtead, we made excellent diſſolvents of ſilver, and, perhaps, much better than theirs. And, in the like caſes, the naturaliſt may gently aſſiſt the tradeſmen, upon account of his knowledge of a vaſt variety of bodies, and their operations, at leaſt, by means of his experiments. An ingenious perſon, whom I knew, upon a general complaint as to the ſcarcity, and advanced price of oak-bark, contrived a way to prepare leather without any bark at all; and that too, much better than uſual in the ordinary way. And, allowing the materials, ſuggeſted by a naturaliſt, be dearer than thoſe in common uſe, yet they

out. But the principal contrivance is the figure of the veſſel which receives the oil. This is made like an ordinary matras, from the lower part of the belly whereof comes a tube, as from an old-faſhion'd crewet, and riſing to the bottom of the neck of the receiver, it bends outwards, ſo that, tho' the veſſel uſually contains but 2 or 3 pints, it conveniently receives, and lets paſs, many hundred pints of the roſe-water, without any neceſſity of being changed; for a change would loſe the ſmall quantity of the oil obtain'd. The water diſtill'd, runs thro' the pipe into a ſecond receiver. Now the oil being lighter than the water, it floats upon the ſurface thereof, and adheres to the neck of the veſſel, as high as the aperture of the little pipe, whilſt the water runs from the bottom of the firſt receiver into the ſecond. *Memoir. de l'Acad.* A. 1700. p. 266.

* The ſubject of trades, with the manner of preparing all ſorts of commodities, in ſeveral countries; the proper market for each, the freight they pay, the price they bear at ſeveral ports, and, numberleſs other particulars relating to this head, are fully treated of by M. *Savery*, in a late *French* Dictionary of Commerce, wherein the particular accounts were, by command of the king of *France*, given in from all the publick offices, and places of employ in that kingdom.

may,

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may, in other reſpects, be far preferable thereto. Thus, tho' diamond powder be vaſtly dearer than emery, yet I, ſometimes, order work to be done therewith upon load-ſtones, as well as gems; for it makes ſo great diſpatch, and the tools employ'd laſt ſo much the longer, as greatly to over-balance the cheapneſs of emery. Common ſpelter-ſolder is much cheaper than that made with ſilver; yet workmen, in many caſes, prefer the latter: and I have found this to run with ſo moderate a heat, as not much to endanger the melting of the delicate parts of work to be ſolder'd. Nay, if this ſilver-ſolder be well made, as ſome I can ſhew, it will ſolder, even upon ordinary ſolder itſelf, with braſs and ſpelter; and ſo fill up thoſe little cavities that may chance to be left in the firſt operation; which is not ſafely performable without a ſolder more eaſily fuſible than the firſt made uſe of.

Tradeſmen may, alſo, be tied down to certain ways of working, when, perhaps, the naturaliſt may diſcern, what they do mechanically, may be better accompliſh'd philoſophically and on the contrary. Gold-ſmiths, perhaps by the direction of ſome chymiſt, boiling their curious ſilver-work, as ſpurs, wrought hilts, *&c.* in ſalt, alum, and argol, give it ſuch a whiteneſs and clearneſs, as it would hardly receive from the bruſh, pumice-ſtone, or putty. And the like cleanneſs, I have learnt from experience, may, immediately, be given to old ſullied pieces of good gold, by means of warm *Aqua fortis*. There are ſome things which, tho' uſually done mechanically, may be better perform'd in a philoſophical manner; but, at preſent, we will obſerve, that much of what is now wrought by manual labour, may, with much more eaſe and expedition, be committed to engines; which being skilfully contrived, ſuch things may, thereby, be effected, as few would imagine. To paſs over ſeveral inſtruments whereon I have, off-hand, play'd various tunes that I never learnt; ſince we ſee timber ſaw'd by wind-mills, files cut by ſlight inſtruments, ſilk-ſtockings wove by a machine, with abundance of the like artificial inventions, not eaſily expreſs'd in few words, what handicraft can there be, that is not performable by engines?

But there are deficiencies of another kind; for work may lye long in hand, require too great pains, a large apparatus of inſtruments, or, ſome way or other, be more chargeable, troubleſome, or laborious than is neceſſary; and theſe inconveniencies the experimental philoſopher may, in many caſes, remedy. I know an inquiſitive perſon who has tann'd as well as the maſters of the buſineſs, and in half the time that they employ'd. In ſome places they have an expeditious way of ſeaſoning particular wood for ſea-ſervice, and other uſes, by baking it in ovens. Our dioptrical glaſs-grinders ſuppoſed they muſt always uſe *Venice*-glaſs for their purpoſe, 'till ſome virtuoſi conſidering, that clearneſs is an inconvenience in an object-glaſs, taught them to ſubſtitute the common green ſort, made in *England*; which, in my opinion, and that of ſome others, is here ſuperior to the other. Several dyers employ our own woad, inſtead of the *Eaſtern* indigo, for dying ſome blues, and other colours, which that grand tincture prepares the cloth to receive. Another ſort of deficiency, or inconvenience, may be the want of durableneſs, as to the being of the thing produced, or the beauty and goodneſs thereof. Of the former kind is the decay of liquors,

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quors, the spontaneous cracking of glass; particularly the fine *Venice* object-glasses of telescopes, will thus flaw, and grow useless, but chiefly in winter; to prevent which, some of the curious carry them in their pockets. Of the latter kind, is the fading of the bowdy, and water-colours in limning; the rusting of shining arms, and polish'd steel. And here, also, the naturalist may be serviceable. Thus the above-mention'd method of making object-glasses for telescopes, of green glass, renders them durable in spight of the weather. I have had pieces of artificial crystal, some whereof soon crack'd, and chang'd their transparency for whiteness; yet another, according to my conjecture, held sound for several winters, and never broke, but by accident. The reason of this difference, I suspect to be, that the former had too great a proportion of fixt salt, and the latter a due one. That the scarlet-dye may be greatly improved, in point of fixtness and duration, beyond the common bowdy, I am convinced by a merchant of *Amsterdam*, who raised a great estate by dying, and was particularly curious in scarlet. This gentleman shew'd me a piece of thick scarlet cloth that would not stain with vinegar, lixivium, or other liquors that he named; nor when cut, appear pale, or white, in the middle; for the dye penetrated quite thorough: and this he could afford at a reasonable price. And that trades may be, considerably, improv'd by those who do not profess them, we have a remarkable instance in the thing we are speaking of *Cornelius Drebell*, the inventor of the true scarlet-dye, was a mechanic, and a chymist, but so far from a dyer, that he knew nothing of the ordinary reds, 'till, taught them by some merchants; whence, by a sagacious conjecture, he discover'd the scarlet.

And supply the desiderata therein.

I come now to the *Desiderata*, whereby, I mean, those desirable perfections that are difficult, indeed, but not impossible to be obtain'd; and of these several may, sometimes, belong to one profession. 'Tis a *desideratum* with the black-smith to render iron fusible, by a gentle heat, and yet preserve it hard enough for ordinary uses; with the glass-man and looking-glass-maker, to render glass malleable *; with the clock-maker, to bring the long pendulum to be useful where there are irregular motions; with the brazier and copper-smith, to make malleable solder; with the ship-wright, to build vessels that will sail under water; with the diver, to procure manageable instruments for conveying fresh air to the bottom of the sea, to suffice for respiration, and the burning of lights; with the say-master, to melt, or cupel ores, or metals, immediately, without the use of bellows or furnace; and, lastly, with the carver and joyner, to fashion wood in moulds like plaister of *Paris*, or burnt alabaster. The obtaining of these *Desiderata*, I am sensible, may be thought chymerical projects: it is proper, however, to propose them, provided they be not, in themselves, im-

* The high value and scarcity of the ancient graved stones, which, in several respects, are preferable to medals, has occasion'd many attempts to render them more universally known. To this end, their impressions have been taken upon sealing-wax, common sulphur, and coloured glass, which, as improv'd by M. *Homberg*, has vastly the advantage over the other two. This gentleman has a way of counterfeiting them to so great a perfection, in glass of different colours, which he can suit to several stones, that the copies have passed upon the virtuosi for originals: so that if glass were actually malleable, they could hardly be made more perfect. For the method itself, see *Memoir. de l'Academ.* A. 1702. p. 250.

possible,

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poſſible, contradictory to the nature of things, and the principles of reaſon and philoſophy; but proceeding, only, from our want of proper inſtruments, and previous means, or elſe ſome difficulties and inconveniencies that lye in the way, or hinder the proſecution of our deſigns. This advantage, at leaſt, will, probably, be hence derived, that, tho' ſagacious perſons ſhould deſpair of attaining them to perfection, ſome approaches thereto may be made. Credible witneſſes have inform'd us, that in ſome countries they ſhoe their horſes, without the aſſiſtance of a forge, by bringing their iron to ſuch a temper, that they keep ſhoes ready made, which they can, eaſily, hammer cold, ſo as to fit them to any horſe: and this being practiſed in hot climates, is the greater conveniency. And, doubtleſs, by various tempers, iron may be greatly ſoften'd, and, afterwards, harden'd; ſince, without antimony, or ſulphur, have melted it in a crucible, and pour'd it out like lead; whereupon it has grown harder than it was originally.

Flixible looking-glaſſes are made with *Selenites*; and all kinds of hollow glaſſes may be eaſily foliated, and turn'd into *Specula*. And, becauſe this may well appear a difficult thing, eſpecially to be done without heat; and, becauſe the uſual ways, delivered about it, fall far ſhort of the character given them; I ſhall here communicate an excellent method of foliating all ſorts of figured glaſſes; the hint whereof I had from an illiterate wandering fellow, in the country, who held his practice, which was confin'd to ſpherical glaſſes only, as a great ſecret. And truly it excelled any I have met with in print. But my mixture is this. Take tin and lead, of each one part; melt them together, and immediately add, of good tin-glaſs, or biſmuth, two parts; carefully ſkim off the droſs; then take the crucible from the fire, and, before the mixture grows cold, add thereto ten parts of clean quick-ſilver; and having ſtirr'd them all well together, keep the fluid in a new clean glaſs. When you go to uſe it, firſt purify it, by ſtraining it thro' linen, and gently pour ſome ounces thereof, into the glaſs, to be foliated, thro' a narrow paper funnel, reaching almoſt to the bottom of the glaſs, to prevent the liquor from flying to the ſides. After this, by dextrouſly inclining the glaſs every way, endeavour to faſten it to the internal ſurface; which done, let it reſt for ſome hours; then repeat the ſame operation, and ſo continue, at times, 'till the liquor is, at length, ſlowly paſs'd over, and equally fixt to the whole ſuperficies; which will be diſcerned by expoſing the glaſs to the eye, between that and the light. Next, gently pour out the ſuperfluous liquor, to be ſaved for the like purpoſe; and, laſtly, with a cloth, well ſprinkled with putty, ſcraped tripoli, or chalk, carefully cleanſe the outſide of the glaſs. This preparation is, alſo, more eaſy and ſafe, than the others I have met with, wherein either arſenic was an ingredient, or the mixture to be uſed hot. I might here, likewiſe, add, that by laying a yellow varniſh upon the external ſurfaces of the glaſſes thus managed, they have appear'd richly gilt, yet ſo bright, as to ſerve very well for mirrors*.

* The ſeveral ways of grinding, poliſhing, and foliating different kinds of glaſſes, for different uſes, in optics, catoptrics, and dioptrics, are clearly and fully delivered by that excellent mathematician *C. Wolfius*, in his *Elementa matheſeos univerſæ*. We have, alſo, an admirable poſthumous piece of the great *M. Huygens, de poliendis vitris*.

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But to return; that malleable ſolder is obtainable, I make no great queſtion; and good ſilver ſolder is already made an approximation thereto. Submarine navigation has been ſucceſsfully attempted by *Cornelius Drebell*; and thoſe concern'd in the experiment affirm'd, that, tho' many were in the boat, they breathed freely, and found no inconvenience for want of freſh air; yet the inventor was neither ſhip-wright, nor ſailor. As for the deſideratum in diving, I have already ſaid, I knew a perſon, who, by means of a ſlight inſtrument, (the whole whereof remains under water, and has no communication with the air above the ſurface,) has continued ſeveral hours at the bottom of the ſea, and removed his engine with him. But *Merſennus* tells us of a much better method, if real, invented and practiſed by one *Barieus*, who was able to continue ſix hours under water, by help of an almoſt incredibly ſmall quantity of air, which, at the ſame time, fed the flame of a lamp at the bottom of the ocean, in a veſſel not much bigger than an ordinary lanthorn. There is, alſo, a method of cupelling, in ſmall quantities, without a furnace, coals, common cupels, or any other veſſels. And, by way of approximation, I made a powder, wherewith I have immediately, without a furnace, melted lead-ore, wherein ſilver is frequently contain'd, into metal, and, perhaps, alſo conſumed ſome part thereof. And laſtly, I am credibly inform'd, that the way of making emboſſed works in wood, with moulds, was lately practis'd at the *Hague*, by the ſecretary of a foreign embaſſador; tho', as to the manner wherein it was done, I could not gain the leaſt hint: but if the thing be true, I ſuſpect it muſt have been perform'd by ſome menſtruum, that greatly ſoftened the wood, and afterwards allow'd it to harden again, as tortoiſeſhell is moulded; or elſe by reducing the wood into a powder, and then uniting it into a maſs, with a ſtrong, but thin glue; the ſuperfluous moiſture whereof being afterwards preſſed out. And I once began a trial of this kind, but was hinder'd from proſecuting it, with a curious glue, whereof I, accidentally, gain'd the hint from an ingenious tradeſman; which I now prepare, by ſteeping fine iſing-glaſs, for twenty four hours, in ſpirit of wine, or common brandy. When the menſtruum has open'd and mollified the iſing-glaſs, they muſt be gently boil'd together, and kept ſtirring 'till they appear well mixed, and, 'till a drop thereof, ſuffer'd to cool, will, preſently, turn to a ſtrong gelly. Then I ſtrain it, while hot, thro' a clean linen cloth, into a veſſel that may be kept cloſe ſtopped. A gentle heat ſuffices to diſſolve this glue into a tranſparent, and, almoſt, colourleſs fluid; which, however, binds ſo faſt, that having, ſometimes, by means thereof, join'd together two ordinary ſquare trenchers, and permitted it to dry of itſelf, the trenchers, that lay one far over another, broke, when a proper force was applied, not where they touched, but elſe-where; ſo that the force of this glue was greater than that which held together the parts of the wood. Nor will this preparation, by reaſon of the ſpirit, corrupt, like other gellies; but the farther advantages hereof I muſt not now mention: I ſhall here, only, add, that having imbued, and mix'd up ſome common ſaw-duſt herewith, ſlightly ſtraining out, thro' a piece of linen, what was needleſs, and forming the remainder, with my hand, into a ball; upon drying it leiſurely, it became ſo hard as not to break, but rebound, when thrown againſt the floor.

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From what we have now ſeen, it appears, that experimental philoſophy may as well advance trades, as an inſpection into them promotes the intereſt of that: and the happy influence they may have on each other, is an excellent means to enlarge the empire of mankind. That the due management of trade is of great concern to the public, appears from our numerous ſtatute-laws, at preſent in force, for it's regulation, wherein the legiſlature has thought fit to give very particular rules and inſtructions thereto relating.

I deſign'd to have added ſomething about varniſhes, but, at preſent, can only ſay, in the general, that they are an uſeful and ornamental production, capable of great improvement.

SECT. V.

Such things may be done philoſophically, as are uſually performed by manual operations.

LET us now conſider how far the knowledge of particular qualities, or the phyſical uſes of things, will enable men to perform, philoſophically, what is commonly done by manual operation. And here, methinks, 'tis a notable proof of human induſtry, as well as a great incitement thereto, that philoſophy can ſupply the want of ſtrength, or art, and the head prevent the drudgery of the hand. The inſtances I ſhall give hereof, which are ſo many trophies of human knowledge, need not to be reduced under particular heads; being only produced as proofs, and having no dependance on each other; I ſhall, therefore, barely ſet them down as they come to mind.

Shewn in ſeparating ſilver from its ore.

The king of *Spain* makes ſuch an advantage of the knowledge we are conſidering, as annually amounted, for ſome time, to many millions. For in his ſilver-mines at *Potoſi*, in *Peru*, they, formerly had a very tedious, laborious, and expenſive method to ſeparate the ſilver from the ore, which is now greatly improved and ſhortened by means of that property of quick-ſilver, to amalgamate with the nobler metals; firſt uſed, in that country, according to *Acoſta*, by *Fernandes de Valeſco*. Their preſent method is, accurately, to grind the ore, firſt pulverized and ſifted, with ſtrain'd quick-ſilver and ſalt; then to boil them, for five or ſix days, in pots and furnaces fitted for the purpoſe; when the mercury imbibes the ſilver and gold, without touching the baſer parts of the ore. The mercury being thus fully ſaturated, is carefully waſhed from the adhering filth, and then, by a ſtrong fire, freed from the noble metals; coming over revived into the receiver, and leaving them behind, it is eaſily reducible into maſſes, and ſeparable the common way. By a proceſs like hereto, ſome of our gold-ſmiths alſo, and refiners, regain, out of their duſt and ſweepings, the ſmall ſcatter'd particles of gold and ſilver, that fly off in their working of them.

In caſting the images of things.

It ſeems to require great ſkill in ſtatuary, to make a figure that ſhall, truly, repreſent the ſize, ſhape, and lineaments of a living human face; yet I lately ſaw this done by a tradeſman, in the following manner. The perſon, whoſe figure we deſign'd, was laid upon his back, with a convenient thing placed

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round the edges of his face to keep away the hair. Then into each noſtril was convey'd a conical piece of ſtiff paper, about three inches in length, open at both ends, to allow of reſpiration. Theſe tubes, being anointed with oil, reſted with their ſmaller ends within the noſe; while the others were ſupported by the hand of an aſſiſtant. Next, his face was lightly oil'd, and his eyes being kept ſhut, alabaſter freſh calcin'd, in a copper veſſel, to its native whiteneſs, and temper'd to a thinniſh conſiſtence with fair water, was by ſpoonfuls nimbly thrown all over his face, till the matter every where lay near the thickneſs of an inch. This done, the ſaid matter preſently began to grow ſenſibly hot, and, in about the quarter of an hour, harden'd into a kind of ſtony concretion; which being gently taken off, and it came away with eaſe, repreſented on its concave ſurface the minuteſt parts of the original face, even to the ſingle hairs of the eye-brows. In this mould they caſt a head of good clay, and therein open the eyes, and, if there be occaſion raiſe the fore-head, or make other neceſſary amendments; then anointing this new face with oil, they, as before, make a ſecond mould of calcined alabaſter, conſiſting of two parts, joined lengthwiſe along the ridge of the noſe, and herein they caſt, with the ſame matter, the fore-part of a head, more like the original than ever I ſaw made by the moſt expert ſtatuary; and yet this is perform'd with ſo much eaſe, that I myſelf ſucceeded the firſt time in attempting it.

Nor need a man be a painter to repreſent the figure of the leaves of plants; for this may be done by holding one in the ſmoke of roſin, gum-ſandaric, camphire, or a common link; whereby the leaf will acquire a blackneſs communicable to white paper when preſſed thereon, which immediately gives the exact ſize, ſhape, and particular ramifications of the fibres thereof. A candle or wax taper will alſo ſerve the turn. And this may be of good uſe to a botaniſt, or a traveller, when they meet with plants whoſe figures are worth preſerving, and they have no conveniency to draw them.

The art of etching. The art of etching, alſo, will furniſh us with an inſtance of the like kind. Copper and ſilver plates may be hereby enriched with delicate figures, without having recourſe to the graver. This is perform'd by drawing a peculiar ſort of varniſh over the plates and then tracing the figures thereon; for the lines thus made, freeing the plate from varniſh in thoſe places, *Aqua fortis*, ſkilfully temper'd, will there corrode, and leave the remaining varniſh'd part untouch'd; and thus afford, under the management of a ſkilful artiſt, as curious cuts as the fineſt graving.

In taking altitudes. But a knowledge of the phyſical properties of things, will, moreover, enable us to perform that wherein mathematics, and the inſtruments it makes uſe of, appear to be neceſſary. Thus, ſuppoſe a candleſtic, that hangs from the top of an high church, be made to ſwing, a philoſopher, who has obſerv'd, that the vibrations of a pendulum, tho' the arches thereby deſcribed be unequal, are, nevertheleſs, perform'd in equal times, as to ſenſe; and that, when the ſtrings whereby pendulums hang are of unequal lengths, thoſe lengths will be proportionable to the ſquares of the number of their ſingle vibrations made in the ſame time; and ſuppoſe, farther, this perſon, provided with a pendulum of any known length, for inſtance, that of a yard; then, I ſay, he may eaſily, without any mathe-

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tical inſtrument, find the height of the church. For the candleſtic and ſhort pendulum being both ſet to ſwing at the ſame point of time, if the candleſtic, for example, makes 9 vibrations, while the other pendulum makes 54, the ſquares of theſe two numbers will be 81 and 2916, and, therefore, becauſe the lengths of the pendulum are proportionable to the ſquares of the number of their vibrations, perform'd in the ſame time, divide 2916 by 81, and the quotient, 36, will ſhew the length of the cord, whereby the candleſtic is ſuſpended to be 36 times longer than the ſhort pendulum; which being equal to a yard, the other muſt be 36 yards. From the knowledge of another phyſical property of heavy bodies, I have found a way to meaſure great heights and depths without the common mathematical inſtruments, and even where they cou'd not be applied. This is alſo done by means of a pendulum, which muſt here be very ſhort, and therefore requires an accurate obſerver. Now, 'tis known, that every heavy body in falling, accelerates its deſcent, ſo that the different ſpaces thro' which it paſſes, at different times aſſign'd, are to each other as the ſquares of the times wherein the reſpective ſpaces were deſcribed. If then it be learnt, by obſervation, how far any heavy body deſcends in a ſecond; the doctrine of proportions will give us, from the time ſpent by a heavy body in falling, the height from whence it fell. This method of menſuration, we, with care, found agreeable to other obſervations. And thus, the depth of any well whatever, to the ſurface of the water, may be known; when quadrants, or the like inſtruments, cannot be uſed to diſcover it. For, if at the ſame point of time that a ſtone is let fall into a well, a pendulum that vibrates quarter ſeconds be let go, and the ſwings counted till the ſound of the ſtone daſhing againſt the water be heard, the thing is done. Suppoſe, for inſtance, that a heavy body deſcends 12 feet, in the firſt ſecond of time, from the beginning of its fall; and the pendulum to have compleated 6 ſingle vibrations before the ſound of the ſtone be heard; our rule will tell us, that ſince the times, in this caſe, are 1 and 6, and the ſquares of theſe two numbers, 1 and 36, the ſtone muſt have deſcended at the end of the ſixth ſecond, 36 times as far as at the end of the firſt; the product, therefore, of 36 by 12, being 432, is the perpendicular depth of the well; or thus, more eaſily, (ſince, as we formerly obſerv'd, falling bodies accelerate their deſcent in a progreſſion of odd numbers from an unit, thus, 1, 3, 5, 7, 9, 11, &c.) the ſtone deſcending 12 feet in the firſt ſecond, will fall 36 in the ſecond, 60 in the third, 84 in the fourth, 108 in the fifth, and 132 in the ſixth; all which numbers added together make 432. And by this means the height of precipices, and the depth of vulcanos, may be meaſured; which were otherwiſe impoſſible. 'Tis true, in ſtrictneſs, ſome ſmall allowance ſhou'd here be made for the ſtone's ſtriking before the ſound thereof is heard; but unleſs the ſpace to be meaſured is very conſiderable, that may be neglected without much inconvenience; ſince we know, from obſervation, that ſounds move in air about twelve or thirteen hundred feet in a ſecond*. And an experiment made by a foreign mathematician

* Sir *Iſaac Newton* ſhews the velocity of ſounds *à priori* to be in the air about 1142 feet in a ſecond; and to this agree the experiments that have of late been purpoſely made to determine the matter. See *Newton Princip.* Ed. 2d. p. 344. *Philoſ. Tranſ.* N° 247. p. 433, &c.

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confirms the doctrine here deliver'd; for he found an heavy body to deſcend 300 feet in about five ſeconds, that is 12 feet in the firſt ſecond*.

In ſplitting thin plates of metal. To ſplit ſo thin a piece of metal as an old ſilver groat, ſeems to require a fine inſtrument; but a trifling phyſical experiment has ſhewn us an eaſier way; for if the metal be placed upon the heads of three pins ſtuck in form of a triangle, and a heap of flower of brimſtone be ſuffer'd to burn out thereon, and you afterwards throw it hard againſt the floor, the upper part will ſeparate from the lower; which, if the coin were not exceeding thin, ſtill retains its priſtine ſhape, I have obſerved a pretty circumſtance or two in this experiment, the knowledge whereof is apt to be miſemploy'd; and the experiment itſelf, tho' ludicrous, may ſuggeſt uncommon ſpeculations to a conſidering naturaliſt, and intimate a particular method of preparing ſilver.

Making marbled paper. From conſidering the fine variety of colours in a ſheet of marble paper, one wou'd ſuſpect them to be careſully laid on with a pencil, or that the whole was printed off from an engrav'd plate; but 'tis made with the utmoſt expedition, only by touching the ſurface of a veſſel full of water, whereon the colours lie to be conveniently blended, by a quick and gentle motion of the artificer's hand, without cauſing them to run too much together. *Kircher*, as I am inform'd, has deliver'd the proceſs hereof.

Rectifying ſpirit of wine. Moſt diſtillers wou'd think it impracticable to rectify ſpirit of wine without diſtillation; yet I have done this by adding thereto well dry'd ſalt of tartar, whoſe pro perty to imbibe the moiſture of the air might well give one the hint; eſpecially ſince oil of tartar *per deliquium* will not mix with dephlegmed ſpirit. And to haſten this operation, the ſalt may be ty'd up in a rag, and ſo plunged in the ſpirit, when by moving it up and down therein, or raiſing it above the ſurface, the water imbibed by the ſalt will fall, in drops, to the bottom.

The uſe of cements. When bodies are ſo brittle, ſmall, ill ſhaped, *&c.* as not to be conveniently held ſteady by Inſtruments; artificial cements are excellent ſubſtitutes for tools. Thus the glaſs-grinders incorporate pitch and aſhes into a ſtiff paſte; wherein, when reduced by heat to a proper degree of ſoftneſs, the glaſſes to be ground or poliſh'd are bedded to what depth, and in what poſition, is thought neceſſary: and being by means of the ſame mixture placed on a proper inſtrument, there they remain, when the cement is cold, firmly fix'd for operation; after which, the cement being again ſoften'd by heat, they are eaſily taken out. The diamond-cutters, who uſe a very vehement attrition, faſten their ſtones in a cement made of roſin and brick-duſt; and one of the moſt ſkilful of them adds ſome ſealing-wax; but plaiſter of *Paris* is here preferable to brick-duſt. And, indeed, ſo many experiments may be advantageouſly made by the aſſiſtance of cements, that I have been curious in preparing a number of them. Many artificers make uſe of powder'd emery, in different degrees of fineneſs, ſome of which are extremely ſubtile; but this hard ſubſtance is not prepared for their ſeveral purpoſes by different ſieves, but by pulverization, ablutions, and proper repeated decantations. And I knew a chymiſt who by this method prepared much better *Crocus Martis*, which he ſold at a more advanced price, than others of his proceſſion.

* All bodies near the ſurface of the earth fall 16 feet, 1 inch, *Engliſh*, in the firſt ſecond of time. See Dr. *Halley*'s propoſitions concerning the deſcent of heavy bodies. *Philoſ. Tranſ.* N° 179. p. 9.

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To hew alabaſter and marble out of the rock is very expenſive and laborious; but by the uſe of gun-powder large portions of both are eaſily obtainable. The method is, to make a perforation, of the deſired length, into the body of the rock, with a tendency upwards, and lodging a convenient quantity of powder in the farther end thereof, the remaining cavity is filled up with rubbiſh and well ramm'd in; a little ſpace only being left for a train, whereby fire may be given to the powder, which will thus break the upper part of the rock into ſeveral pieces of a manageable ſize. And by this means, a little varied and improved, ſome ingenious acquaintance of mine, who were imploy'd by the public to raiſe vaſt piles, have lately blown up, with a few barrels of powder, many hundreds, or perhaps, thouſands of tuns of common rock. *The obtaining of ſtone from the quarry.*

To faſhion glaſſes for watches, or the like purpoſes, into a convex or concave figure, they ſeem to require grinding, or ſome particular ſkill in the management; yet I have found, from experience, that a ſmooth and flat piece of glaſs, of a competent thickneſs, being carefully laid upon a ſhallow concave cylinder of iron, ſo, that the round edges of both mutually touched each other, the heat of a fire, warily applied, will ſoften the glaſs, and ſuffer it to ſink into the form required. This way, 'tis true, will not always exhibit the preciſe figure one wou'd wiſh; but when ſkilfully practiſed, it ſucceeds ſo often, that ſome ingenious artificers have quitted their uſual method of making watch-glaſſes for this, which is much more cheap and eaſy. In ſome parts of *England* may be found various kinds of talc, or *Lapis ſpecularis*, and there are of them very cheap and plentiful, tho' to reduce it to powder by the mortar and ſieve is exceeding tedious and laborious; but actual flame will ſpeedily reduce ſmall pieces thereof to a perfectly white calx. And a ſagacious acquaintance of mine, thus, alſo, preſently reduced large lumps, by caſting them red-hot into cold water. This operation has an affinity to that wherein ſome chymiſts granulate maſſes of gold and ſilver, by pouring them, ſtrongly melted, from a competent height into cold water, whereupon there happens a diſſilition of the parts of the metal; when many ſmall portions thereof fall to the bottom. But the ſofter metals, as tin, and lead, are better and more expeditiouſly granulated by the proceſs juſt mention'd for talc. And by twice or thrice repeating the ignition and extinction, I have immediately brought cryſtal flints to a fitneſs for making counterfeit gems. *Figuring of glaſſes, and reducing talc to powder.*

Conſiderable art ſeems uſed to counterfeit fruit in wax, eſpecially when a particular lemmon, or orange, *&c.* is exactly repreſented: yet this art may be learnt in an hour or two; for, having the fruit to be imitated, 'tis only burying it half way in a clay coffin, the edges whereof, as well as the extant part of the fruit, being oil'd; and nimbly throwing on it temper'd alabaſter, or plaiſter of *Paris*, to a conſiderable thickneſs; which, when concreted, and taken off, is a half-mould; wherein the fruit being now placed, with its other end upwards, a ſecond half-mould may be obtain'd, as the former; and when the two are join'd together, a little colour'd wax, melted, and brought to a due heat, being poured thro' a hole, made in any convenient part of the mould, and preſently ſhook every way therein, will, when cold, lively repreſent the original. And here it might appear an extraordinary piece of art to cauſe ſo great a cavity as there will remain in the counterfeit fruit, and to render the repreſentation ſo perfect with ſo ſmall *Making images in wax.*

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ſmall a quantity of wax; whereas, the bare ſhaking of the mould, together with the expanſive force of the included air, applies the wax ſo cloſe to the whole internal ſurface, that 'tis thereby form'd into one large film, and ſeems difficult to be ſeparated without injury, which muſt enſue, did not nature here again aſſiſt the artiſt, and cauſe the mixture, when it cools, to ſhrink from the mould.

Graving of hand-writing. I know a famous graver who writes but a bad hand, and yet with his tool he can imitate the fineſt performances of the moſt celebrated writing-maſters. This has appear'd ſurprizing to virtuoſi themſelves, that a man, with a ſtiff iron inſtrument, ſhou'd write incomparably fairer upon a tough copper-plate, than with a good pen upon paper. The method itſelf is kept as a great ſecret, and I cou'd not learn a curious particular or two; yet by putting queſtions, and by ſome trials of my own, I have obtain'd the ſubſtance thereof; which is this. The copy to be engraved is wrote by an excellent hand, with a peculiar kind of ink, as black as the common; and the copper-plate, being moderately warm'd, is rubbed over with a certain white varniſh, and ſuffer'd to cool; then the paper being gently moiſten'd, that it may readily communicate its ink, the writing is applied to the prepared ſurface of the plate, and ſo paſſed thro' a rolling-preſs; by which means the ink adhering to the varniſh, leaves the letters very conſpicuous; whence 'tis eaſy, with a fixed needle, to trace the ſtrokes, thro' the varniſh, upon the plate, which being afterwards cleanſed, the letters are finiſhed with the graver, and the work printed off in a rolling-preſs, as common cuts.

Taking off written characters, or printed cuts. I have alſo taken off written characters without the help of a preſs, by laying the moiſten'd paper ſmooth upon the varniſhed copper, and rubbing it hard thereon with a convex piece of glaſs, or the like; provided the ink be good, and thick laid on. For varniſh, here, I have uſed the purer ſort of virgin wax; and for my ink, the fine *Frankford* black, as the painters call it, which was gradually and carefully ground with water, till it obtain'd the conſiſtence of common ink; but no gum is to be added, leſt that ſhou'd hinder its coming off.

There is, likewiſe, a way whereby printed cuts are ſo far taken off, that, at leaſt, the outlines, and principal ſtrokes, may be ready copied for graving. If the print be not above a year or two old, the paper need only be well moiſten'd with water, as for printing, with the uſual ink of cuts; but if it be more ancient, it ſhou'd be laid to ſoak all night in water, and afterwards ſuffer'd to hang in the air 'till it becomes dry enough for the preſs. The paper thus prepared, is to be laid with its printed ſide next the plate, thinly caſed over with white wax, which is thus to be committed to the rolling preſs, whereby an impreſſion of the cut will be gain'd.

And copying, at once, a whole page of writing. But there's one thing that ſeems more than any, hitherto mention'd, to require immediate manual operation; I mean a method of tranſcribing, at once, a whole page of writing. Whether this be performable with eaſe and cheapneſs enough for common uſe, is another queſtion; but, that the thing is poſſible, by phyſical means, I am convinced from my own experience.

Hitherto ſuch inſtances have been produced wherein philoſophical knowledge may be ſubſtituted for manual dexterity, mechanical tools, and mathematical inſtruments; to theſe I ſhall ſubjoin one, to ſhew, that a mathematician, and a mechanic, by being acquainted with a ſlight phyſical property of ob-

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vious bodies, may perform what mathematical learning, and mechanical skill, wou'd not otherwise accomplish.

That a massy body, some hundred thousand pounds in weight, shou'd be raised by means of a little water, seems very surprizing; yet this was done at *Constantinople*, as we learn from *Busbequius*; who tells us, "that a monstrous "obelisk, thrown from its pedestal in the city, had remain'd at its length for "many ages, till in later times an architect appear'd, who, for a certain sum, "undertook to set it again upon its base; and having to this end prepared a- "bundance of machines, he therewith raised it within an inch of its due height; "when the spectators imagin'd it cou'd not be elevated higher; but he, rely- "ing upon his knowledge, of nature, commanded water to be brought him, "which being, for several hours, thrown upon the ropes that supported the "pillar, they gradually contracted and so set it upon its base, to the great sur- "prize of the vulgar." And to render this the more credible, the like is men- tion'd by many eminent authors, as having been elsewhere practised; and the thing is allowed of by that great master of mechanics, *Galilæo*. *Instances wherein a knowledge of nature may improve mechanical skill.*

The usual methods of catching fish among us, require pains and skill; but the illiterate *Americans* have preferable ways, from the knowledge of a physical property of a certain wood, wherewith they impregnate the water, and stupify the fish so, that they roll upon the surface, and are easily taken with the hand. And this appears probable from the intoxicating preparations we are here possess'd of, which tho' slight, fall not much short in their effect; and having particularly enquired of a learned physician who came from that country, he assured me it was true, and that he saw the *English* use the same method, by tying a log of this wood, which they call dog-wood, to the stern of their boats. The hair growing on any part of the body, may, without the use of any instrument for that purpose, be very expeditiously taken off, to appearance, by the roots; whence it is again of a much slower growth. This is effected by a property of the natural production call'd *Rusma*. *Belonius* gives us the method wherein they use this drug in the *East*; but I had made experiments with a parcel of it, before I met with his observations. I mix'd it, in fine powder, with an equal weight of strong pulveriz'd quick-lime, and permitting them to soak for a short space together in a little fair water, they become a soft paste, which I spread thin upon that part of the body I wou'd free from hair; and suffering it to remain on about three minutes, I wipe it off with a linen cloth dip'd in water, and find the hair taken away by the roots, without any discernable inconvenience to the part. Thus I several times repeated the experiment, and more than once perform'd it upon my self.

To measure time exactly, may to some appear scarce practicable without springs, wheels, or the common contrivances; yet so simple a thing as a bullet fix'd to a string will do it. For if that be made to measure a little less than ten inches, from the point of its suspension, to the centre of the bullet, 'twill swing half seconds with less inequality than a good watch; and may, therefore, be of great service in making astronomical and other observations of a short duration, wherein accuracy is required. And by means of a pendulum, a skilful musician of my acquaintance teaches his scholars to keep time in singing. But the best way, in observations, is to make the vibrations as long as possible,

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ble, and when they begin to decreaſe, to give a freſh impulſe to the ſwinging weight, leſt by growing ſhort, they ſhou'd not be ſo well counted.

By knowing the velocity of ſounds in the air, 'tis eaſy to meaſure diſtances without geometrical inſtruments, or where they wou'd be uſeleſs. The foundation hereof is already deliver'd; for ſince all ſounds, whether great or ſmall, move 1380 feet in a ſecond; if a gun be fired on one ſide of a river, how inacceſſible ſoever, 'tis but letting fall a ſhort pendulum as ſoon as I ſee the flaſh, and counting the vibrations till I hear the ſound, to gain the diſtance of that gun from the place wherein I ſtand. Suppoſe, for inſtance, the report be perceiv'd two ſeconds after the light, I conclude the river to be 2760 feet over.

And by this means may be ſolved a problem that, nakedly propoſed, might ſeem impoſſible; I mean, without geometrical inſtruments, to meaſure, in a dark night, the remote diſtance of one ſhip under ſail from another. For, ſuppoſing one of them to fire two or three of her guns, a pendulum may be ſet a going at the firſt, taken as a ſignal; and its vibrations counted that paſs between the flaſh and report of the ſecond. And, by the way, I have thought, that if the velocity of echoes, which are only reflected ſounds, cou'd be well determin'd, ſailors might, ſometimes, in the dark make uſeful eſtimates by means thereof, as to their diſtance from the coaſt, or conſiderable rocks. For tho' they cannot juſtly conclude upon diſcharging a gun, how near they are to the ſhore, becauſe ſome parts thereof may lie leſs remote than thoſe which reflect the echo; yet were that ſound to follow immediately after the original report, there's reaſon to ſuſpect the land as near as the pendulum ſhews the echoing-place to be*.

SECT. VI.

Mankind very ignorant in natural things.

BUT we may venture to aſſert, there is ſcarce a production in nature, the uſes whereof to human life are hitherto thoroughly underſtood. This propoſition being very intelligible, needs no explanation; but as it is an ungrateful

* Sounds are now commonly uſed, as the moſt exact means for determining the diſtance of one place from another; and the moſt accurate ſurveys are made by the help of them, ſince their velocity has been preciſely determined. And upon this foot Mr. *Whiſton*, ſome time ſince, propoſed a new ſurvey of *England*. 'Tis ſtill more remarkable, that he and Mr. *Ditton*, improving upon this hint, by adding light to ſound, and joining the aſſiſtance of the eye to that of the ear, advanced a method of diſcovering the longitude at ſea. Their deſign was, that from a certain number of ſtationary hulks, or ſhips riding at anchor in convenient parts of the ſea, at due diſtances from each other, large fire-ſhells ſhou'd, at 12 a clock, every night, be thrown from mortars, to the perpendicular height of a mile, or more, and there afford a large blaze of white light. For, if from a ſhip out at ſea the aſcent of this ball of fire be obſerv'd, the ſailors will thence know the difference of time between the meridian of their ſhip, and that meridian in the plain whereof the fire-ball aſcends; ſo that the point of the compaſs from whence the light came being obſerved, and the place where the exploſion was made found mark'd on the ſea-chart, the longitude at ſea muſt thence be diſcovered. They alſo propoſed other methods for finding the ſame, as from obſerving the time that paſſes between the firſt ſeeing the light, and hearing the ſound of the mortar; or from the angle wherein the ball appears at its utmoſt height. But all of them, tho' very ingenious and good in the theory, are defective in the practice; being exceeding troubleſome, and yet precarious. Theſe inconveniencies Mr. *Whiſton* is now attempting to remedy by means of the dipping-needle.

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paradox, it requires a full demonſtration; becauſe it cannot be admitted without ſuch a confeſſion of our ignorance as muſt tacitly accuſe us of lazineſs. However, we may ſay, with *Seneca*, a greater knowledge and command of nature wou'd have been gain'd, had it not been preſumed we were already arrived to a much more conſiderable degree than, indeed, we are, in compariſon, of what remains behind obtainable. I ſhall, therefore, offer ſome conſiderations to rouze our curioſity, by ſhewing how defective it has been, and how much of nature continues undiſcover'd to exerciſe and reward our induſtry. It muſt be remember'd, that I here ſuppoſe the uſefulneſs of nature's works to mankind chiefly depends upon the knowledge we have of their properties; and, conſequently, that the more we learn of theſe, the more uſes we receive therefrom; ſo that whatever aſſiſts us to diſcover things which, probably, may prove uſeful, is a phyſical uſe thereof, tho' in itſelf not immediately practical.

The works of nature imperfectly conſider'd even in their peculiar qualities.

I obſerve, in the firſt place, that very few of nature's works have been ſufficiently conſider'd, even as to thoſe qualities that properly belong to them. There's a kind of *terra incognita* in every natural body, reſerv'd for the diſcovery of futurity. For there are various artificial means of finding out the properties of things, by chymiſtry, optics, ſtatics, *&c.* which require ſuch ſkill, induſtry, and inſtruments in their application, that few have the curioſity and ability to examine materials in all theſe ſeveral methods; yet unleſs this be done, various properties thereof, ſome of which are, probably, capable of uſeful applications, are likely to remain undiſcover'd, as might be eaſily ſhewn by an induction of particulars. But many things, doubtleſs, muſt continue unknown in the abſtruſer productions of nature, when even the moſt obvious and familiar objects hide abundance from us. To inſtance in our own bodies, wherewith we are highly concern'd to be acquainted; how many diſcoveries have been made in the preſent age that remain'd unthought of for above two thouſand years? The happy ſucceſs of *Harvey*, *Aſellius*, *Pecquet*, *Bartholine*, and *Wirſungius*, are remarkable inſtances hereof. In bodies ſo familiar as thoſe of eggs and chickens, tho' *Ariſtotle*, many ages ſince, was ſolicitous about their hiſtory; yet ſo little, till within theſe few years, was known concerning them, that it grew a hot diſpute, whether the chick were formed of the white, or the yolk; when our excellent *Harvey* ſhew'd, as I have alſo obſerved, that it proceeds from neither of them, nor even the treddle; but that ſpeck which appears in the coat of the yolk. *Kepler* is ſaid to have been the firſt who told the world ſo obvious a thing as, that the parts of ſnow are of an hexagonal figure, in a diſcourſe wrote on that ſubject. However, I find, *Oalus Magnus* makes mention of it; and I myſelf have frequently obſerved the ſame thing; eſpecially about the beginning of the ſeaſon; for that is not its conſtant figure; but 'tis ſurprizing, the diſcovery ſhou'd not be made before the preſent age. As common a liquor as vinegar has been for many ages, yet, that it often abounds with ſhoals of living creatures, which thro' a microſcope appear like eels, was a diſcovery which ſeem'd ſo new but a few years ago, that when I obſerved it, to ſome virtuoſi in *England*, as a phenomenon to be ſeen with the naked eye, they thought me deceiv'd, till their own eyes fully aſſured them of the contrary. That the milky way ſhou'd for two thouſand years paſs for a meteor is not ſtrange, conſidering the minuteneſs of the ſtars

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that compoſe it; nor do I, for the ſame reaſon, wonder, that the predeceſſors of *Galilæo* reckon'd only ſeven planets; nor ſuſpected *Venus* to repreſent the ſame phaſes with the moon: theſe inſtances however, ſerve to ſhew, that many attributes of bodies are ſcarcely diſcoverable without artificial helps. But what may not mankind overlook, when the ſun itſelf, the moſt conſpicuous body in the univerſe, has vaſt dark ſpaces, perhaps bigger than *Aſia* or *Europe*, frequently generated and deſtroy'd upon his ſurface; whereof even the aſtronomers took no notice till the excellent *Galilæo*, and the induſtrious *Scheiner*? In the year 1660, *April* 27, about 8 a clock in the morning, I my ſelf obſerved a ſpot in the lower limb of the ſun, a little towards the ſouth of its equator, which was enter'd about $\frac{1}{11}$ of the diameter of the ſun itſelf, being about $\frac{1}{160}$, in its ſhorteſt diameter, of that of the ſun, and its longeſt about $\frac{1}{70}$ of the ſame. It diſappear'd upon *May* 9, in the morning, tho' we ſaw it the day before at about the ſame diſtance from its weſtern limb, a little ſouth of its equator; tho' it firſt appear'd from the eaſt limb, a little ſouth alſo of its equator. It ſeem'd to move faſter in the middle of the ſun, than towards the limb. It was a very dark ſpot, almoſt quadrangular, and encloſed round with a duſkiſh cloud. We firſt obſerved this very ſame ſpot, for figure, colour, and ſize, to be re-enter'd the ſun *May* 25, when it appear'd to be in a part of the ſame line it had formerly traced, and was enter'd about $\frac{1}{11}$ of its diameter at 7 a clock in the evening. At the ſame time there appear'd another ſpot, which was juſt enter'd not above $\frac{1}{132}$ part of the ſun's diameter. It appear'd longeſt towards the north and ſouth; and ſeveral ſmall clouds ſeem'd to be diſperſed about it *. The diſcovery of theſe ſpots, indeed, was made by means of teleſcopes, inſtruments unknown to the ancients; yet had mens curioſity been raiſed to that height the nobleneſs of the object deſerv'd, part thereof, at leaſt, might have been obſerved without them; for I find by an *Italian* letter of *Galilæo*, that ſome of his acquaintance, after he had rouzed their curioſity, deſcry'd ſpots therein with their naked eyes.

Things have different relations to one another in different places, ſeaſons, &c.

It might here be remark'd, that one reaſon why men are ignorant in the uſes of ſuch things wherewith they ſeem well acquainted, may be, that the difference of climates and places occaſion new relations between them, and thereby endow them with unſuſpected qualities. I ſhall not here enumerate the different properties of bodies commonly referr'd to the ſame ſpecies, whether of plants, animals, *&c.* in almoſt every country; as, that ſpiders are not venomous in *Ireland*; and, that *Iriſh* wood, in general, if the tradition be true, is an enemy to poiſonous creatures: I will only add two inſtances; the one to manifeſt what different climates may do; the other to ſhew the unexpected influence of different places, perhaps, in the ſame climate. The inhabitants of hot regions, where it never freezes, who deride the relations of what happens in the colder, wou'd

* From abundance of obſervations more lately made of theſe ſpots, and publiſh'd in the *Philoſophical Tranſactions*, the *French Memoirs*, the *Acta Eruditorum*, *&c.* it appears that they are nearer to the ſun than the planet, *Mercury*; that yet they are not actually on the ſun's ſurface, but at ſome diſtance from it; that new ones frequently appear and diſappear, and are, therefore, probably form'd of the ſun's exhalations, or are its clouds. Hence it ſhou'd ſeem that the ſun has an atmoſphere, like that of the earth, wherein, ſince theſe ſpots or clouds fall back again to the ſun, ſeveral changes muſt neceſſarily happen in that luminary, as well as in its atmoſphere.

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never imagine that water cou'd be broken in a mortar like a dry body, be tranſported in open carriages, kept all the year round in that form, and, laſtly, communicate an intenſe coldneſs to other water in the ſummer. And the leſs inquiſitive among ourſelves can ſcarce believe that water will ſerve for highways, in travelling, the marching of armies, the training of artillery, and for a field of battle; yet in the more northern countries all this is practiſed upon the ice in the winter ſeaſon.

The ſecond inſtance, is the declination of the magnetic needle from the true north and ſouth points; with the variation of the ſame. For, altho' the loadſtone has been long admired, and ſince its happy application to navigation, generally known, and peculiarly ſtudied; yet that the needle does not in ſome places point directly, perhaps not by many degrees, to the pole, as it will in others, is no ancient obſervation, being aſcribed to *Sebaſtian Cabot*. And, according to our famous *Gilbert*, he muſt have lived ſince then who firſt remark'd that ſtrange and conſiderable alteration of the unexpected phenomenon, its declination in the ſame place, towards the eaſt or weſt, in proceſs of time; the truth whereof I cou'd confirm by obſervations of my own, compared with thoſe of modern authors. And as the ſame bodies may have different qualities and uſes in different places, ſo may they alſo, if examin'd, and employ'd at different times, ſeaſons, or peculiar periods, wherein they undergo ſome ſignal changes. But theſe are not obvious to every eye, as when fruit grows ripe, or wine turns to vinegar; but ſuch as require ſkill and curioſity in the obſerver. Thus, while common urine is freſh, the volatile and pungent ſalts are ſo clogged with other particles therein, that near nine parts in ten muſt uſually be evaporated before they will riſe; and afterwards a conſiderable heat given to force up the laſt. Now, tho' the tradeſmen who deal in urine commonly overlook the difference; yet if the urine be barely kept for ſix or ſeven weeks, the ſaline and noble parts will in that time have ſo extricated themſelves, that a very gentle heat will raiſe them firſt, and leave that phlegm behind which in the former caſe preceded.

That the *Thames* water, when carried long voyages, and into hot climates, will have a very offenſive ſcent, the common putrefaction of ſtagnant water may perſuade us; yet 'tis found, if that be kept long enough, tho' in the ſame veſſel, and a hotter climate, it will at length grow ſweet and potable again. And this I have not from vulgar tradition, but receiv'd, by enquiry, from two very inquiſitive perſons, upon their own knowledge; one whereof had particularly obſerv'd it in ſailing between *Europe* and *Africa*; and the other in going and returning from *America*. And I the rather mention this, becauſe ſeveral other waters have, as I am inform'd, the faculty of recovering after putrefaction, as well as that of the *Thames*; whereto 'tis uſually ſuppoſed peculiar. And having had the curioſity to try how the rougher kind of water, that will not bear ſoap, might be remedied; an induſtrious perſon, whom I employ'd, aſſured me he had met with pump-waters, that, barely by ſtanding a few days, wou'd gain this property.

Coriander-ſeeds, when freſh gather'd, are obſerved to have ſuch an acrimony, that ſome ancient phyſicians account them venomous; and diſpenſatories uſually order them to be corrected with vinegar, or the like; but the more accurate

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accurate obſervers tell us, that this ſeed, in a competent time, loſes, of itſelf, this offenſive quality. And the like in both reſpects is obſerved by ſome eminent apothecaries as to the roots of aron.

'Tis allow'd, that vegetables, however managed, unleſs firſt reduced to ſoot, will afford no dry volatile ſalt, like that of animal ſubſtances; yet, by diſcourſing lately with a very ingenious perſon, as alſo by ſome experiments made to examine diſtill'd liquors, I was ſatisfied there are various vegetables growing common in *England*, which, gather'd, and laid together, at a certain ſeaſon, and diſtill'd at a particular juncture, will yield a volatile ſpirit that in its ſcent, taſte, and various effects, as turning ſyrup or violets green, hiſſing with acid ſpirits, *&c.* reſembles the volatile ſpirits and ſalts of animal ſubſtances: and, what appears ſurprizing in this great change, the ſecret whereof I wiſh I durſt communicate, it is effected without any addition.

Nor are vegetable and animal ſubſtances only thus alterable in their texture; but even mineral bodies themſelves. 'Tis a complaint in chymiſtry, that tho' we are taught to make the ſalt of diſtill'd vitriol by immediately taking the *Caput mortuum* thereof, freed from the oil by a violent fire, and extracting all its ſaline parts by repeated affuſions of water; yet this means will not obtain the ſalt. But I found, by enquiring of thoſe who diſtil large quantities of oil of vitriol, that if the *Caput mortuum* be ſuffer'd to lie a conſiderable time in the air, 'twill be ſo impregnated with new ſaline particles, as to be worth a ſecond diſtillation. And, as we formerly mention'd, there are quarries of ſolid and uſeful ſtone, ſome whereof has been employ'd about ſtately buildings, that I have ſeen, whoſe property, as we have alſo heard of other kinds, is, that being dug at a particular ſeaſon of the year, it proves thus good and durable; but if employ'd at a wrong time, makes but wretched ſtructures; as has been found by ſad experience.

Time and place are, indeed, two of the principal, but not the only things whoſe variations may diſcover unheeded properties in natural bodies; even the ſlighteſt circumſtances may afford new uſes in ſolid and laſting materials. Optical glaſs-grinders have complain'd to me that their convex glaſſes will frequently prove veiny; and thereby render the labour beſtow'd upon them almoſt uſeleſs; becauſe they are unable to diſcover theſe blemiſhes by the moſt careful examination, till a conſiderable time be ſpent in the work; and even then they continue inviſible while the glaſs is held at an ordinary diſtance from the eye; but upon removing it ſome feet therefrom, thoſe defects become apparent: ſo ſerviceable may an encreaſe of diſtance be where one wou'd leaſt expect it.

Bodies muſt be conſider'd mathematically before their properties can be known.

The change of poſture may ſeem a ſmaller circumſtance than the change of diſtance; yet Dr. *Gilbert* has obſerved, and I have found it true, that perpendicular iron rods, as the bars of a window, by long ſtanding in that poſition, acquire magnetic poles; ſo that the needle of a dial, for inſtance, applied to the lower part of ſuch a bar, will have its ſouthern end attracted; whereas, the upper extremity of the ſaid bar will ſeem to repel that, and attract the northern. And here I cannot but obſerve, that men will ſcarce ever be able to know all the properties and uſes even of familiar bodies, till they ſhall have been mathematically conſider'd; for there are many things thereto belonging, which, probably, a naturaliſt, how curious ſoever he may be, will never otherwiſe diſcover. Various

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inſtances, which prove this aſſertion, have been already produced; however, the thing is of ſo great importance for naturaliſts to be convinced of, that I ſhall again inculcate it upon them with a few more examples. Since the firſt ages of the world men muſt, ſometimes, have beheld ſwinging bodies; yet till *Galilæo* no one took notice that their vibrations, whether great or ſmall, were perform'd in equal times. This diſcovery required a mathematical eye; and ſome of the uſes of it we have ſeen already.

That, water running out at a hole near the bottom of a veſſel deſcribes a parabolic line, or one that nearly reſembles it; and, that, in the like experiments there's a determinate proportion aſſignable between the perpendicular height of the water, and the diameter of the hole; whence the quantity that will iſſue out thereat in a given time, with its velocity, may be computed; was not, that I know of, obſerv'd before *Galilæo* and *Merſennus* attempted to adjuſt this matter.

As frequent as are the occaſions we have to take notice of air, water, and glaſs; our modern maſters in optics have made great diſcoveries as to the different refractions of the rays of light in thoſe ſeveral mediums, with other particulars, unregarded by ſuch as are not ſkill'd in that ſcience. 'Twas from a geometrical contemplation of the drops of dew upon the graſs and leaves, with the colours the riſing ſun uſually paints therein, that the great *Des Cartes* raiſed a neat hypotheſis to account for the phenomena of the rain-bow. For he found, that in one particular angle made at the ſpectator's eye, by a ray of light proceeding from a certain part of the drop, and the imaginary ſtrait line reaching from the eye to the ſun's centre, the appearance of red was exhibited; in another, that of yellow; in a third, that of blue, *&c.* and in ſome, no colour at all. 'Till this time the world was ignorant of ſuch conſiderable properties of ſpherical diaphanous bodies illumin'd by the ſun. Thus alſo, tho' wood and timber muſt have been daily broke, by weights; yet till *Galilæo* applied geometry to this ſubject, the reſiſtance of ſolid bodies in breaking, by means of their own weight, or that of others, ſeems not to have been ſuſpected reducible to calculation. And a virtuoſo of my acquaintance, can, from a muſical inſtrument, whereof he is maſter, obſerve a property of metals not dreamt of by chymiſts. He hereby finds, that equal wires of different metals, will, upon due tenſion, yield ſounds different in ſharpneſs by determinate muſical notes, or the diviſions thereof. It were eaſy to add various other remarks, made by *Merſennus* and *Galilæo*, as to the force of guns encreaſing proportionably to their length, but decreaſing when they come beyond a particular ſtandard; the parabolic line wherein bullets ſhot out of a gun are ſaid to move; and the like mathematical properties of things, which geometricians, aſtronomers, engineers, *&c.* have already obſerved. But I ſhall only ſubjoin one inſtance more to prevent our imagining that the moſt familiar objects wherein the feweſt properties ſeem diſcoverable, have been ſufficiently conſider'd. What phenomenon in nature occurs more frequently than the falling of heavy bodies? yet not a ſoul, that we know of, once made a fair attempt to determine their acquired velocity till *Galilæo* reduced it to the proportion formerly mention'd; wherein moſt of the ſucceeding mathematicians have acquieſced. In a word, till geometry, mechanics, optics, and the like ſciences, be more generally and ſkilfully applied to philoſophy, many properties and uſes of natural things, muſt, doubtleſs, remain unknown.

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Even the moſt obvious qualities, and their uſes, may be overlook'd.

And as we have hitherto obſerved of bodies, ſo will I venture to add of qualities, and various other things in nature, that even the moſt obvious may have attributes and uſes which learned men overlook. That black bodies, for inſtance, are ſooner heated by the ſun than white ones, or thoſe of any light colour, is, perhaps, but very little taken notice of; yet this is demonſtrable in many particulars, as may eaſily be try'd in a black glove, and a white one; or in two eggs, one whereof is black'd. Cold is one of the moſt familiar qualities we deal with; and tho' little is apt to be expected therefrom, it will perform the office of heat in ſpirit of wine, and preſent us with inflammable ſpirit from beer, and other liquors ſmaller than wine*. And, to paſs by *Paracelſus*'s proceſs of making the eſſence of wine by freezing all the phlegm; thoſe who have ſailed into the frigid zone aſſure us, from repeated experiments, that not only wine, but beer, by a congelation of their more aqueous parts, will ſeparate therefrom a ſtrong, hot, ſpirituous liquor. Even in our own temperate climate ſome odd ſeparations may be made by cold; as, particularly, of a liquor from oil, much finer, and more ſpirituous than the reſt. I know an eminent artificer who held it as a great ſecret, to reſort, in hard froſts, to large jars of oil, and there take out the fine thin fluid from the cracks in the congeal'd part; this being much better than the other to preſerve things from ruſt; and for this purpoſe, alſo, ſome watch-makers, who were made acquainted with its virtue, highly eſteem'd it. But it were tedious to inſiſt on all the inſtances produceable of applications that may be made of colours, ſound, levity, elaſticity, fermentation, and putrefaction; and endleſs to proſecute what might be afforded by more general and active ſtates and faculties of bodies. For, not only motion, and reſt, fluidity, and firmneſs, gravity, and the like, have a more univerſal influence on things than even philoſophers obſerve; but the leſs general properties of matter, reckon'd among particular qualities, as reſpective gravity and heat, may be ſo diffuſive and applicable to ſo many different purpoſes, that 'tis a queſtion whether all the uſes of that particular degree of heat in fire will be diſcover'd while the world endures. I muſt not here omit, that many more qualities in the moſt known bodies wou'd, probably be remark'd, did we not want ſuch a meaſure of particular curioſity, for of the general I don't here ſpeak, as might be juſtly expected; ſuch a curioſity, I mean, as to the things wherewith we familiarly converſe as we could ſcarce want but thro' lazineſs or prejudice; whence we preſume to take for granted what we ought to try and examine. Thus, that falling bodies deſcend the quicker in proportion to their weight, has been believ'd in the ſchools ſince the days of *Ariſtotle*, and prevented the truth from being taken notice of; namely, that all bodies, how different ſoever in bulk and weight, deſcend with equal velocity; till inquiſitive men lately found it by experiments.

That water by being froze contracts into a leſs compaſs, is ſtill the opinion both of the vulgar and generality of learned men; yet the quite contrary is evident from experience: and the bubbles that are uſually found in ice, with its floating upon water, might make a conſidering man ſuſpect it. The air we breathe, has, for many ages, been ſuppoſed a body endow'd with poſitive levity; but if

* Dr. *Beal* has obſerv'd, that a vehement degree of cold will ſerve to diſtil ſpirit of wine; and he ſeems to think it might be applied to other purpoſes. See *Philoſ. Tranſ.* N° 56. p. 1140.

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men had the curioſity to examine, they wou'd find it heavy: even that common way of condenſing it in a brown bladder confirms this aſſertion; for, allowing the included air not to be in its natural ſtate, but crowded together; yet if the particles whereof it conſiſts be actually light, they ought to weigh lighter when the bladder is filled with them. However, there are other methods of making the experiment clear of this objection.

Large ſounds are commonly thought to move ſwifter than ſmall ones: 'tis true, indeed, they don't both reach to the ſame diſtance; but, 'tis known from late obſervations, that they go with equal velocity. That a load-ſtone, which by immediate contact takes up iron, ſhou'd have this power greatly encreaſed, when capped, or by a piece of a ſteel, of a proper ſhape, interpoſing between the body and it, ſeems ſtrange; and what the ancients, who admired its attractive virtue, never vouchſafed to try: but he muſt be a novice in magnetics who can doubt hereof, ſince *Gilbert* wrote. Magnetics is ſo large a field, that it wou'd be tedious to enumerate all the truths I cou'd therein deliver; and theſe, too, are ſuch as few wou'd think probable enough to deſerve a trial. Unſlaked lime is generally believ'd, both by the vulgar and the learned, to grow hot by *Antiperiſtaſis*, if cold water be poured thereon; and, contrariwiſe, when the water is heated; and ſome have even uſed it as an argument in the proof of other things: but a few experiments might eaſily diſabuſe them; for by the affuſion of various liquors, actually warm, I have made lime ſlake, at leaſt with its uſual violence; and, on the contrary, I have preſerved other parcels of it, for a long time, unſlaked in liquors actually cold, whereto it has imparted no ſenſible heat.

The quality of the inſtances here alledged renders it needleſs to encreaſe their number, ſince a greater inducement can hardly be deſired for us to expect the diſcovery of new properties in the works of nature, were our curioſity but duly employ'd in making experiments, than, that many have been found which ſeem'd ſo unlikely, that 'twas thought in vain to ſearch for them. It might here be added, that bodies of the ſame denomination, whence men uſually expect only the ſame operations and uſes, may yet have peculiar ones, and ſometimes different from each other. We may farther conſider, that the faculties and qualities of things being, generally, only certain relations either to each other, or to men; when that whereto they relate is better underſtood, many of them, wherewith we are already tolerably acquainted, may be found to have uſeful properties hitherto unobſerved. By the qualities of things being relative, I mean, they have ſo great a dependance on the ſtructure or conſtitutions of other bodies diſpoſed or indiſpoſed to be acted upon thereby, that, did no ſuch objects exiſt, thoſe qualities in the bodies ſaid to be endow'd therewith, cou'd be only diſpoſitions to pruduce ſuch effects, if convenient objects were not wanting. Thus, for example, the faculty of a key, as to its opening or ſhutting, depends upon the

New properties of bodies ariſe from diſcovering their new relations.

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correſpondent lock; but if no ſuch thing as that exiſted, the key wou'd be a bare piece of iron, of a determinate ſize and ſhape. So, many a thing that ſeems uſeleſs to us, whilſt conſider'd only with regard to itſelf, may hereafter prove highly ſerviceable, when other bodies, whereon 'tis peculiarly fitted to act, ſhall come to be diſcover'd. Tho' iron was known and employ'd from the earlieſt ages; tho' its uſes are numerous; and tho' it had paſſed thro' the hands of chymiſts, phyſicians, mineraliſts, *&c.* and been employ'd to numberleſs different purpoſes, for ſome thouſands of years; yet it conceal'd its nobleſt and moſt uſeful property, that of pointing north and ſouth, when touched with a load-ſtone, till within theſe three or four ages.

After all the vain attempts of chymiſts to fix the fluid body of quick-ſilver, which, tho' the ſharpeſt froſt fails to congeal it, the vapor of melted lead will ſometimes render conſiſtent, tough, and hard. Upon what variety of bodies has vinegar been employ'd; and how many purpoſes had it ſerved, eſpecially by means of its accidity, before it was put to the diſſolving of crude or calined lead; when it exhibited a ſweetneſs beyond that of ſugar?

Spirit of urine has long been known to chymiſts, and ſeems likely to prove an excellent menſtruum for ſeveral bodies; but after having been employ'd to diſſolve various ſolids, 'twas improbable it ſhou'd coagulate with ſo thin, light, and volatile a fluid as ſpirit of wine; yet if theſe two liquors be ſufficiently pure, they afford, when mix'd, a ſtrange and perfectly white concretion. The ſpirituous parts of urine, likewiſe, without being ſeparated from the others, have a ſtill more extraordinary faculty when duly applied to muſk. Of this I was inform'd by a ſcholar, who, living in *China*, had often ſeen muſk made. 'Tis there the practice, he told me, that either before or after this drug is put into the cod, or bags, prepared of the animal's ſkin, to hang it in a neceſſary-houſe, but not low enough to touch the filth; that ſo it may receive the fetid exhalations of the place, for ſome days, whereby its leſs active ſcent is fetched out and heighten'd. The ſame perſon, having carried a parcel hereof from that country to ſome remoter parts of the *Indies*, found the voyage had greatly decay'd its ſtrength, which he reſtored by tying it up in a bladder wherein many ſmall holes were made with a needle, and laying it in ſuch a place as was juſt mention'd. An eminent phyſician of *Rome*, alſo, tells it as a ſecret, practiſed among the perfumers of that city, to recover the ſcent of decay'd muſk, by keeping it wrapp'd up in linnen well moiſten'd with rank urine. *Gypſum* is put to ſeveral uſes by the ſtone-cutters, thoſe who mould plaiſter or wax, and other artificers; but one wou'd not ſuſpect it ſhou'd alſo be applied as a remedy to canary; yet, that large quantities of it are mixed therewith, is not only a tradition among the dealers in that wine, but comes to me confirm'd by an eminent wine-merchant who lived many years in the *Canaries*: and a curious eye-witneſs aſſur'd me, that about *Malaga*, a large quantity of it is tunn'd up with the juice of the grapes. Silver

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is a noble metal, and has been very long known and employ'd; yet one very fine uſe thereof was diſcover'd only ſince the art of annealing upon glaſs came to be practiſed. For, prepared ſilver, or even the crude metal, being here burnt on a glaſs plate, will tinge it of a fine yellow or golden colour. There are alſo ſeveral mineral earths, and other courſe foſſils, of uſe in this art; which, by means of fire, impart tranſparent colours to glaſs, and ſometimes very different from thoſe of the bodies themſelves. Hence it appears, that we can ſcarce ever be ſure we know the ſeveral uſes obtainable from the bodies we converſe with; ſince upon the invention of a new art or trade, whereof a vaſt variety will, perhaps, hereafter be diſcover'd, many unſuſpected applications of things may chance to be made. Lixivia, prepared of common aſhes, have long been very familiarly uſed to waſh linen; but this ſeems very remote from the property they have, when ſtrong, to turn ſyrup of violets, or the bruiſed flowers of that plant, to a perfect green, in an inſtant. Red is an obvious, and, generally, a pleaſing colour; but ſo offenſive to the eyes of a turkey-cock, that it cauſes great ſigns of offence in that fowl. Oak-leaves, whereof no extraordinary property is uſually obſerved, being, when freſh gather'd, immerſed in mineral chalybeate waters, will turn them blue, or black, according to the proportion and ſtrength of the two ingredients. It does not ſeem probable that charcoal ſhou'd be a proper thing wherewith to cleanſe and brighten particular metals, or to promote a clearneſs, and give a gloſs to ſome tranſparent bodies; but mathematical-inſtrument-makers, gravers, *&c.* find it excellent to poliſh their braſs and copper plates, after they have been rubbed clean with powder'd pumice-ſtone. The more curious, will, for this purpoſe, burn it a ſecond time, and quench it in a convenient fluid. Plates of horn are alſo poliſhable the ſame way; and to thoſe of metal, a gloſs may be afterwards given with tripoly. We may here obſerve, that not only the nature of the body to be work'd on, but ſome particular circumſtances relating to it, may alſo contribute to the effects of ſuch experiments as we have mention'd. Thus it ſeems improbable, that water, being apt to run out wherever it finds a vent, ſhou'd of itſelf become the fitteſt inſtrument for cloſing leaky wooden veſſels; which it does by plumping up and ſwelling the adjacent parts. And upon the like effect depends that odd experiment, ſo much talk'd of by eminent *Engliſh* ſailors, of immediately ſtopping a ſmall leak in a ſhip by thruſting thereinto a piece of ſalt beef; for the ſea water, being freſher than the brine that is imbibed, penetrates into the compact body of the beef, opens the ſalts, and cauſes it to ſwell ſo as to bear ſtrongly againſt the edges of the broken planks, and thereby hinder the water from flowing in.

Let us next conſider, that a body in aſſociation may have new uſes, and ſome of them quite different from what it had alone; I mean, two or more materials, being conjoin'd, may be qualified to act on a third, upon account of freſh properties thence accruing to the compoſition. As tin is flexible, and yields but a dead ſound, who

Bodies in conjunction may have new uſes.

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wou'd dream, that a conſiderable uſe of it ſhou'd be to make a leſs yielding and better ſounding metal more ſtrong and ſonorous? yet bell-metal is principally compoſed of tin and copper. In the preparation of common ink, the infuſion or decoction of galls is either yellowiſh or reddiſh; and the ſolution of vitriol, as that concrete partakes more of iron or copper, will be green or blue; yet 'tis the mixture of theſe two that gives the blackneſs. That oil ſhou'd be a principal ingredient in a tenacious cement, and the only liquid one employ'd, cou'd not well be ſuſpected; yet, not to mention my own trials as to this particular, an ingenious man, well verſed in water-works, aſſures me, the beſt method he knows to cloſe and mend the pipes of ſubterraneous aqueducts, is with dry tobacco-pipe clay, pulverized, and mix'd with a large quantity of ſhort flocks, and carefully beat up, with linſeed oil, into a ſtiff paſte. And before I learnt this, having occaſion to try ſome experiments relating to cements, an ancient artificer, employ'd to keep in order the conduits that brought water to *London*, alſo told me, in exchange for a lute I taught him, that oil was a chief, and the only liquid thing in the cement he uſed about that important work. Lead is one of the moſt opake and flexible bodies in nature; one wou'd not therefore, expect it ſhou'd make three parts in four of a tranſparent and exceeding brittle mixture; yet this is eaſily obtain'd by chymiſtry in the *Vitrum Saturni*, which I myſelf have often made of calcined lead, and powder'd flint, or ſand. Who wou'd expect, that the fixed ſalt of kali, which is of a ſtrong and fiery taſte, eaſily ſoluble in water, or even the moiſture of the air, ſhou'd be one of the two principal ingredients of a ſubſtance perfectly inſipid, and undiſſolvable even in the moſt corroſive and penetrating menſtrua? yet ſuch a ſubſtance is glaſs. I confeſs, I doubted whether there was any large quantity of alkalizate ſalt in glaſs, till enquiring of an ingenious maſter of a glaſs-houſe, he told me, they obtain'd many pounds in an hundred above the weight of the ſand employ'd to make it; and that the alkali did not only ſeem to promote the fuſion of the ſand, but largely contribute to compoſe the glaſs. And that bodies in conjunction are applicable to new uſes, and, perhaps, to ſome quite different from thoſe they had when ſeparate, may be ſhewn by many examples. Thus, oil, tallow, and the like unctuous materials, which of themſelves ſpot and defile apparel; will, when ſkilfully join'd with others, tho' but a lixiviate ſalt and fair water, greatly contribute to make ſoap, whereby ſuch blemiſhes are eaſily removed. Salt of tartar is a fix'd body, and has a fixing quality; yet when skilfully aſſociated with the moſt fixed body, gold, diſſolved in *Aqua regia*, the gold precipitated by this incombuſtible ſalt, becomes ſo exceeding volatile, that by a leſs degree of heat than would kindle any known body in nature, 'twill give a report vaſtly more violent than that of gun-powder. And, what is no leſs ſtrange, the inflammable body of ſulphur being mixed herewith, will, tho' fired, hinder this very inflammable gold from lighting; and thereby turn it into a medicine, ſaid to be diapho-

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retic; which, by means of a crucible, I have long continued in the fire *without* loſs. That the proportion, alſo, of ingredients may greatly *vary* the effects and uſes of mixtures, we have a remarkable inſtance in the mineral call'd by the glaſs-men *Manganeze*; which, tho' of itſelf it be courſe and dark, and when added to the materials of glaſs in too large a proportion, makes that black ſort which is ſold in the ſhops; yet a moderate quantity of it is uſed to turn glaſs red, and a ſmaller to render it clear and tranſparent. Again, a body, by different preparation or management, may be fitted for new, and perhaps, unſuſpected purpoſes: for the qualities of materials generally depending upon the texture of the ſmall parts whereof they conſiſt, the ways of ordering them, whether by an addition, detraction, or tranſportation of their component corpuſcles, ſo as to produce any remarkable change in their texture, bid fair to introduce new properties and uſes. Thus, mere tradeſmen, by varying the viſible ſhape of certain portions of iron, and connecting ſome of them after a particular manner, have converted it to various purpoſes; as we ſee in the ſhops of iron-mongers, clock-makers, *&c.* And to give a more phyſical inſtance, in the ſame metal, what an immediate alteration is made in the inviſible texture thereof by fire? The ſame bar of iron, by means of that and water, is hardened, and brought to a condition fit for drills, ſprings, *&c.* to make which, different degrees of temper are required in the metal. But to leave ſuch caſes where no new ingredient is either added to, or taken from the body to be alter'd, and come to thoſe wherein the addition ſeems to have but an inconſiderable ſhare in the change. Paper, beſides its common uſes, may be made into frames for pictures, fine emboſs'd work, and curious moveables; by ſteeping a convenient quantity of the beſt white ſort, for two or three days, in water, till it becomes very ſoft; then reducing it, by the mortar, and hot water, into a thin pulp, to be laid on a ſieve to drain off its ſuperfluous moiſture; and afterwards putting it into warm water, wherein a conſiderable quantity of fiſh-glue, or common ſize, has been diſſolv'd; for being now with a ſponge preſſed into moulds to acquire the figure deſign'd, it may, when taken out, be ſtrengthen'd, as occaſion requires, with plaiſter, or moiſten'd chalk, and when leiſurely dried, painted, or overlaid. Another uncommon uſe of paper, is to ſtop up cracks or fiſſures in wooden inſtruments and veſſels to hold water; for in this caſe it will forcibly dilate and fill the place wherein 'tis lodged. The ſugar-cane was known in many countries and ages, as to the ſweetneſs of its juice, wherein ſugar never ſeems to have been made therewith, for want of knowing how to coagulate it into ſo durable a ſubſtance. Tobacco, alſo, was a noted plant in the *Weſt-Indies*, but ſuffer'd yearly to periſh, like other herbs, till modern induſtry found the way to cure it, and at length improve it, merely by force of ſkill, to a condition fit for ſale and tranſportation over all the globe. The leaves of indigo, likewiſe, which wou'd otherwiſe periſh like thoſe of common ſhrubs, have by the ſole way of managing them,

Varying with the different proportions of their ingredients, and ways of management.

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them, which too conſiſts in deduction rather than addition, long been made to afford a laſting pigment; which is one of the moſt ſtaple commodities of the *Eaſt-Indies*. I might add the great uſes we make of madder, woad, and many other periſhable plants, by the methods wherein they are order'd; but theſe are not comparable to the advantages formerly mention'd of the plant *Mandiocha*, which, tho' actually poiſonous, yields, by an eaſy management of the ſavage *Americans*, both excellent bread and drink. The ſhreds and parings of leather, parchment, or vellom, only by being long boil'd in fair water, and ſtrain'd, make ſize; which is very uſeful in ſeveral trades: and, to inſtance in an eaſy experiment, fine red ſtands, and hanging ſhelves, are coloured with ground vermillion, temper'd herewith; being, when dry, laid over with common varniſh. It ſeems ſcarce credible, that ivory ſhou'd, without any addition, afford the moſt perfect black yet known; which is obtainable by burning it a while in a cloſe veſſel or committing it in ſeveral folds of wet paper, to hot coals and aſhes. By the way, this ivory-black is ſo excellent in its kind, that ſcarce any thing ſerves ſo well for foils to the nobleſt gems and diamonds: and a jeweller, whom I employ'd, confeſs'd, he thus uſed it when his work was deſign'd to be extraordinary. That the ſtrait-gut of an ox ſhou'd, by the management of illiterate tradeſmen, become tranſparent, and, tho' reduc'd to a thinneſs exceeding that of paper, continue incredibly firm and tough, ſeems ſtrange; but 'tis a practice with gold-beaters to include thin plates of gold between theſe fine membranes, and thereon to beſtow many ſtrong blows with a vaſt, heavy hammer, made on purpoſe, ſo as to attenuate and dilate the metal, whilſt the ſkins continue firm and unbroken; as I have with wonder obſerv'd. The inſtances here produced are, generally, ſuch as nature alone, or aſſiſted by illiterate perſons, affords us. It cannot, therefore, be queſtion'd, that more ſkilful management may produce great changes in bodies, and fit them for new uſes; eſpecially, if chymiſtry, mechanics, and mathematics, ſhou'd contribute their aſſiſtance. That mathematical ſkill may teach men to order natural things ſo as to obtain other uſes from them than are commonly thought of, may appear from ſeveral particulars. By barely giving to a piece of glaſs a priſmatic figure, that body will beautifully repreſent all the colours of the rain-bow in an inſtant. A concave foliated glaſs, or metalline ſpeculum, will burn vehemently by reflection; and a convex glaſs, or even water in the ſame figure, will do the like by refraction. A concave ſpherical vial, indeed, will not of itſelf do this, tho' it tranſmit the rays; but it will when filled with water. And, perhaps, ice itſelf, that is free from bubbles, and reduced to a ſpherical figure, will ſerve for the ſame purpoſe. But this effect would be far greater, if two concave glaſſes of like ſhape, equal ſize, and truly ground, were by a frame join'd cloſe at their edges, ſo that the cavity between the inſide of the glaſſes of the frame may be filled with water; for, thus the whole will ſerve as a double convex glaſs; ſome whereof I have ſeen, which by this

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this contrivance may be made much larger than the common ſort, that conſiſt of a ſingle peice of glaſs. Glaſs-ſtopples are made by giving them an almoſt conical figure, and a ſurface, fitted by grinding to touch cloſely with the inſide of the neck of the bottle; yet this ſimple mechanical contrivance is ſo excellent, that neither *Aqua fortis*, or the moſt ſubtile ſpirits; can poſſibly eſcape where 'tis uſed. And by this means I remember ſpirit of ſal-armoniac preſerv'd exceeding freſh and ſtrong, for ſeven years.

Chymiſts, we ſee, can from ſome wild fruits, or the lees of liquors, draw an inflammable ſpirit, which may ſerve, in many caſes, for that of wine; from the dryeſt ſolid woods, or bones of animals, force large quantities of ſpirit, oil, and phlegm; and from the opake body of lead, mix'd with ſand, and a few grains, perhaps, of metalline pigment, ſome of them can, in two or three hours, make various artificial ſtones that ſhall pleaſingly imitate rubies, emeralds, *&c.* What improbable effects are ſometimes producible by a ſlight chymical preparation, appears from the *Bolonian* ſtone; which, tho' its appearance promiſe nothing of the kind, acquires by calcination a ſtrange property of ſhining in the dark, ſoon after having been expoſed to the ſun. And, truly, very trivial circumſtances in the management of a body, will, ſometimes, produce conſiderable and unlikely eſſects. 'Tis commonly obſerv'd, that ſalt diſſolved in water ſtrongly prevents the coagulation thereof; yet the ſame ſalt externally applied to water, greatly contributes, with ſnow or ice, to make it freeze artificially; and is ſo neceſſary hereto, that they, without the aſſiſtance hereof, will not uſually in our climate readily produce any ice; as I have purpoſely tried. There is a certain powder, which by the proportion and mixture of nitre, its chief ingredient, with the reſt, obtains ſo odd a texture, that if expoſed in a crucible to the fire, as uſual, 'twou'd blow up with great violence; yet if inſtead of kindling it from the bottom upwards, that be done from the top downwards, no danger enſues; but it makes a powerful flux for the reduction of metalline powders, wherewith 'tis mix'd, into a body. But, laſtly, the generality of effects being not producible by one unaſſiſted production either of nature or art, but by the concurrence of ſeveral; whoever is ignorant of the nature or properties of all the other bodies wherewith the ſubject of an experiment either is or may be uſefully join'd or employ'd, cannot diſcern all the effects of that experiment. And a body that ſeems uſeleſs to the main and ultimate end, may greatly contribute in ſome intermediate or ſubordinate part of the operation. Thus, tho' ſpirit of wine will ſcarce ever extract a red tincture from the flowers of ſulphur; yet theſe being open'd and flux'd together, with an equal weight of ſalt of tartar, I have found them, in a few minutes, yield, with a gentle heat, a blood-red ſolution or tincture in that ſpirit well rectified; which being afterwards freed from the ſuperfluous menſtruum, affords a much finer balſam than that prepared with oil of turpentine. 'Tis uſually thought impoſſible to gild iron with water-gold, that is by means

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means of quick-ſilver; yet I know a very ingenious tradeſman who cou'd perform it by the mediation of another body, before the application of the amalgam. His way was, firſt to lay the iron, to be gilt, over with copper, by help of ſome diſtill'd liquors temper'd with other ingredients, wherein the metal being very carefully immerſed, the experiment ſucceeded; otherwiſe the iron wou'd be ſpoil'd. But to prevent this inconvenience, he caſed it, when bright, with copper, by frequently immerſing it in a ſtrong ſolution of good vitriol, that contain'd copper, in warm water; ſuffering it each time to dry of itſelf, till copper enough remain'd thereon. And by this certain, cheap, and eaſy way, iron may be gilt, as copper, with the amalgam of gold, and mercury. It muſt here be obſerved, that, tho' the ſeveral parts of an experiment may, in moſt caſes, be purely phyſical or chymical, for inſtance; yet it might frequently be more advantageouſly contrived, that while one part is phyſical, the others ſhould be perform'd by particular arts, as ſtatics, mechanics, hydroſtatics, *&c.* ſo that by a concurrence of different parts of knowledge to the ſame operation, many things will, queſtionleſs, be perform'd which have not hitherto been attempted or dreamt of. For whoever is ſkill'd only in one of theſe parts of learning, muſt needs be crampt in his attempts, and confin'd to operate by ſuch means and inſtruments as lie within his reach; which muſt, therefore, often prove defective. Thus not only handicraft-trades do many of them mutually aſſiſt each other, but the nobler arts ſometimes ſtand in need of the meaner, as well as of one another. The maſters of catoptrics, 'tis true, are well acquainted with the properties of various kinds of *ſpecula*; but in order to procure them in perfection, they muſt have recourſe to the chymiſt or the founder; and for the poliſh, to the ſmith, ſtone-cutter, *&c.* To make a pair of organs requires ſkill in the theory of muſic, a knowledge in wood as to its conditions, and the ways of ſeaſoning it, in turnery, joinery, and the effects and mixture of metals, with the method of caſting them to form ſonorous pipes of the due figure, and with the proper qualifications. Bells, and other muſical inſtruments, might afford us many more examples, to this purpoſe; but I proceed to thoſe of another kind. Tho' the nature of nitre and brimſtone be ever ſo attentively conſider'd apart, that will never enable any one to make the more conſiderable uſes of either, till they are ſkilfully join'd together, with charcoal, in gun-powder; which, conſiſting of theſe three different ingredients, neither being of itſelf ſufficient to produce the effect of the compoſition, but all jointly contributing thereto, affords a remarkable inſtance of what I wou'd ſhew. Another conſiderable uſe of ſulphur will remain unknown to him who is unacquainted with ſome properties of common oil and calcin'd alabaſter. For by means hereof moulds may be made wherein to caſt off the impreſſion of emboſſed-work on metals; which, tho' it appear ſtrange, is eaſily practiſed. The method is this. About the work, whoſe impreſſion is deſir'd, having made a ledge of clay, and carefully oil'd the whole; brimſtone melted in a cloſe-

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cover'd veſſel, to prevent its firing, is, whilſt hot, poured gently upon the emboſſed metal, in a large quantity, that ſo the mould may be the ſtronger: about the edge of this mould make a border of clay, as before, and lightly oil the internal ſurface of both; then pour gradually into it, to the thickneſs of about the quarter of an inch, a mixture made up, with calcin'd alabaſter and water, to the conſiſtence of ſtiff honey; which ſoon growing hard, may be taken out of the mould. And thus I have, ſometimes in a few minutes, eaſily obtain'd the image of a coin, medal, or landſcape. And, as I lately hinted, particular bodies may often conduce to the principal effect of an operation, by performing ſome ſubordinate or intermediate offices remote from the ultimate effect. Thus *Aqua fortis*, tho' it eagerly corrodes both ſilver and braſs; contrary to all probability, greatly contributes to the ſilvering of braſs, in the following manner, which is more applauded than known. Firſt, this menſtruum excellently ſerves to cleanſe emboſſed work, or pieces of metal whoſe unequal ſurfaces prevent the application of tripoly, or the comon powders for cleaning of braſs; for ſuch bodies being lightly waſh'd over therewith, and immediately thrown into fair water, the foulneſs will be thus fretted off, and the work not disfigured: and on the ſcouring of the metal the ſucceſs of the experiment greatly depends. Secondly, fine ſilver muſt be diſſolv'd, by the ſame menſtruum, in a broad bottom'd veſſel of glaſs or glaz'd earth; and the *Aqua fortis* being afterwards evaporated, water is to be poured upon the remaining calx, in a ſufficient quantity, to diſſolve it. This water, alſo, muſt be evaporated, and the like operation repeated as often as there's occaſion; the fire being encreaſed towards the latter end, ſo as to leave a perfectly dry and white calx, which will thus be tolerably freed from the fetid fretting ſpirits of the *Aqua fortis*. Of this calx take one part, and an equal meaſure, not weight, of common ſalt, and of the cryſtals of tartar, and mix them together into a fine powder; then having firſt plunged the ſcoured braſs into fair water, rub ſome of the power upon it with your wet fingers, till the cavities of its ſurface be ſufficiently filled therewith. Laſtly, waſh the metal well in fair water, and give it a gloſs by rubbing it hard with a dry cloth. This waſhing, tho' it be expeditious, cheap, and requires no quickſilver, may be made to laſt ſome years, or is eaſily renewable when it begins to wear.

To proceed; we ought not to conclude, that a particular uſe is unobtainable from things, becauſe the like is had from others ſuppoſed of a quite different nature; for among various inſtruments employ'd to the ſame purpoſe, ſome may exceedingly differ as to other qualities, yet agree in that which is requiſite to perform the office required. Thus, tho' roſin, and ſal-armoniac, for inſtance, differ in colour, ſcent, taſte, weight, and degree of hardneſs; tho' the one be a vegetable production, the other a compoſition of ſeveral ſalts; this eaſily diſſolvable in water, that not ſo but in oil; with numberleſs other diſagreements between them; yet either of them ſingly is applicable to the tinning of

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braſs or copper veſſels. So, likewiſe, there appears no affinity between water, ſand, and tin; yet they equally ſerve for hour glaſſes; tho' the ancients, 'tis ſaid, employ'd only the former for that purpoſe.

'Tis no leſs certain, that we ſhou'd not imagine, becauſe a certain body is uſeful on ſome occaſions, it cannot therefore be converted to other purpoſes, that ſeem of a different or oppoſite nature. For this I ſuppoſe poſſible, firſt, from the different conſtitution of the body work'd upon by the ſame agent: thus the heat of the Sun at once melts wax, and hardens clay; ſpirit of vinegar, that, digeſted on filings of copper, acquires an abominable taſte, gains a great degree of ſweetneſs from ſtanding upon thoſe of lead; and, laſtly, ſpirit of ſalt, that diſſolves iron and copper, like *Aqua fortis*, precipitates ſilver diſſolved by that menſtruum. Secondly, a parcel of matter, uſually conſider'd as the ſame body, may contain parts of very different natures; whence its operations will be diverſified. Thus, when ſome unripe minerals are calcin'd with nitre, its inflammable parts burn up and diſſipate in ſmoke what is volatile and combuſtible of the minerals; but by virtue of the remaining alkali of the nitre, ſeveral other parts of the mineral are thereby render'd far more fix'd, and capable of enduring the fire, than they were originally. So ſulphur contains ſome parts that make it more inflammable than either nitre or oil, yet abounds with acid and vitriolic particles, that ſtrongly reſiſt the flame in ſeveral other bodies; and the fire thereof, beſides its common effect ſeen in matches, acts, from its acidity, in a different capacity upon ſome metals, eſpecially iron, and alſo upon red-roſe leaves, which are turn'd white by its fumes. 'Twere eaſy, if neceſſary, to alledge many other inſtances of the different actions of different parts of bodies, and alſo to produce other caſes wherein things are convertible to uncommon uſes; but thoſe already offer'd may ſuffice. I have not here meddled with the medicinal uſes of things, tho' theſe wou'd furniſh me with numerous inſtances to my preſent purpoſe; ſince abundance of bodies, both natural and artificial, uſed as remedies, have various and apparently contrary effects. The different properties of rhubarb both to purge and bind, and of ſpirit of wine to heat or cool, as internally or externally uſed, were formerly mention'd. Mercury, taken crude, has ſometimes proved innocent or effectual in caſe of worms; but when raiſed into fumes and receiv'd into the body, too often occaſions dangerous commotions. But the various and different operations of antimony, according to the temper and diſpoſition of the patient, and preparation of the mineral, may, alone, ſuffice to ſhew, that the medicinal uſes of things might greatly have ſwelled the number of my inſtances, had I thought fit to have dwelt thereon. And tho' what I have all along inſiſted upon, almoſt wholly relates to the neglected uſes of particular natural bodies, it muſt not be imagin'd there are no advantages to be had from other natural things which have hitherto been unknown or overlook'd. By natural things, I mean, the different ſtates of matter, as to rarity and denſity, fluidity and firmneſs, putrefaction

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and fermentation, with the more active qualities of heat, cold, gravity *&c.* the laws of local motion among the parts of matter, and the preſent fabric of the univerſe, eſpecially that of the terreſtrial globe and its effluvia.

SECT. VII.

MANY obſervations and experiments, tho' communicated for true by ingenious authors, or unſuſpected eye-witneſſes, or, perhaps, recommended by our own experience, may, upon farther trial, fail our expectations: and this unhappineſs will ſometimes befal even thoſe who are exquiſitely ſkilled in the manner of making trials of different kinds; and that upon account of the materials employ'd, or ſome miſtake in their management, not eaſily to be diſcern'd. Theſe materials may be diſtinguiſh'd into natural and factitious, genuine and adulterate, ſimple and compound, *&c.* but we forbear to inſiſt on ſuch diviſions, and content ourſelves to throw what we have to ſay on this ſubject into a few comprehenſive obſervations. *Why attempts to repeat experiments fail of ſucceſs.*

And, firſt, ſeveral experiments fail of ſucceſs becauſe they are at one time tried with genuine materials, and at another with ſophiſticated ones, of different qualities; for, ſophiſticated bodies, may, by foreign mixture, or a deceitful way of preparation, produce ſuch effects, as had they been genuine they wou'd not have done. It's ſcarce imaginable to one not very well vers'd in drugs and ſimples, how generally they are adulterated by the fraudulent avarice of the ſeller; eſpecially when the ſophiſtication is very gainful. It has lately been much complain'd of by ſome cultivators of clover-graſs, that from a great quantity of the ſeed, no graſs has been produced, tho' neither the ſoil nor the ſower were in fault. This, ſome analogical obſervations lead me to ſuſpect, ariſes from the want of heart in that ſuperannuated ſeed ſometimes ſold in the ſhops. And one of the moſt eminent and ſober chymiſts of *Amſterdam*, who was alſo an *Indian* merchant, aſſured me, that moſt of the cinnamon, and cloves, brought into *Europe*, is firſt, in the *Indies*, defrauded of its aromatic parts. And to give a more appoſite inſtance to our purpoſe; how conſpicuous ſoever little animals, like eels, are in ſome vinegar, yet there are many parcels of that fluid wherein 'tis in vain to ſeek for them. *Firſt, becauſe the materials differ in point of genuineneſs.*

Sublimate is commonly ſophiſticated with arſenic; and what different effects ſuch ſublimate may have, from that which is faithfully prepared, not only upon metals, but upon human bodies, when made into *Mercurius dulcis*, thoſe who are acquainted with the noxious qualities of arſenic will readily imagine. And, indeed, as for chymical preparations, there are ſcarce any vulgarly ſold in ſhops to be rely'd on. For my part, I have ſo often met with chymical preparations inſincere, that I dare

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scarce trust any, either in the administration of physic, or so much as in any considerable experiment except what my own furnaces afford, or those of persons of known skill and integrity. Having occasion to use some spirit of salt, whereof I was unprovided, I sent for it to a chymist, who himself prepared it; and tho' I gave him his own price for it, yet at the first rectification, even in a retort, a single pound of it afforded six ounces of phlegm; and being farther rectified, in a high body, and a gentle heat, the remaining spirit let go a scarce credible quantity of the like nauseous liquor; and after all this separation of phlegm, it was not pure enough for what we intended. Complaining of this to an excellent chymist of my accquaintance, he sent for some of the same kind of spirit to a very eminent distiller of it, who passes for a very honest man; but this, besides its weakness, was sophisticated either with spirit of nitre, or *Aqua fortis*; which betray'd itself by its peculiar odious smell; whilst spirit of salt, genuinely prepared, is commonly of a greenish colour, and has often a grateful scent. 'Tis not enough, in many cases, to separate the aqueous parts by dephlegmation, as many chymists content themselves to do; but some liquors contain also an unsuspected quantity of small corpuscles of an earthy nature, which, associated with the saline ones, clog or blunt them, and thereby weaken their activity. Such liquors, therefore, to be well depurated, must be distill'd off with a slow fire, that the dry feces may be left behind in the bottom of the glass. We have sometimes taken of the better sort of spirit of salt, and having carefully dephlegm'd it, remov'd it into glasses less tall, and gently abstracting the whole spirit, there remain'd in the bottom and neck of the retort, whence 'twas distill'd, a surprizingly great quantity of a certain dry stiptical substance, for the most part of a yellowish colour. And the spirit of salt, after this second depuration, was so chang'd, that it seem'd to be a much nobler liquor than before. But what different effects wou'd be produc'd by two such different liquors as true spirit of salt, and that which is mix'd with the spirit of nitre; the former whereof will precipitate silver, when the latter has dissolv'd it?

In their species Secondly, even when the materials, employ'd about experiments, are genuine, there may be a considerable difference betwixt substances of the same kind and name, and which pass, without suspicion, for bodies of perfectly the same nature. For, tho' antimony, quick-silver, gold, copper, *&c.* are severally, without scruple, suppos'd of the same nature, and perfectly similar to themselves; yet there is a manifest difference in them, as well as in vegetables or animals of the same species. Thus, as the white-rose, the red, and the damask, differ greatly from one another, tho' all three are roses; and as the sour and sweet orange are very different betwixt themselves and both of them from the *China*-orange, tho' all are oranges; and as the hound, the grey-hound, the spaniel, the tumbler, the mastiff, *&c.* are very differently qualified, tho' all of them are dogs; so the different parcels of antimony to be met with in mines, have different qualities, tho' all of them are antimonial concretes.

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concretes. There is, indeed, this difference betwixt the variety to be obſerv'd in vegetables and animals, and that in minerals, that the former is more obvious to the eye, and betrays itſelf by ſomething remarkable either in the ſize of the creatures of the ſame kind, or in ſome peculiar ſhape or colour; whereas, minerals appearing to the eye either perfectly ſimilar, as metals, or at leaſt to conſiſt of but two or three diſtinct ingredients, as cinnabar, and ſome other mineral concretions; the diverſity to be found betwixt minerals of the ſame denomination, is hardly diſcernible till experience diſcovers it. The womb of a mineral is not always, like that of an animal, a place ſecured from the intruſion of all bodies not of kin to that included in it; but a mineral, being generated in the bowels of the earth, lies open and expoſed to other mineral juices or ſteams of what different nature ſoever; ſo that I have obſerv'd marcaſites and metals, marcaſites and ſtones, ſalt and ſulphur, *&c.* blended in the ſame lump of matter. And I have ſometimes found, in a great maſs of one ſort of mineral, ſmall parcels of another of a quite different kind, perfectly enclos'd in the ſubſtance of the former. And theſe intruding bodies being coagulated, and, perhaps, ripen'd together with the former by length of time, are not eaſily ſeparable or diſtinguiſhable when firſt dug out of the ground, much leſs after they are melted. For the miner, aiming only to obtain a quantity of ſuch a metal, or other mineral, as is vendible under a determinate name, has no deſign, nor, perhaps ſkill, to make nice ſeparations of the heterogeneous bodies to be met with in his ore; but melts as much of them as he poſſibly can promiſcuouſly together, and then ſells the product to the merchant, or the chymiſt, for that metal or mineral whoſe outward form and properties it has; tho' the metal for which it paſſes be but the predominant ingredient of the lump. So that many other minerals may, in ſmall quantities, here lie conceal'd, and upon occaſion be diſcover'd by exquiſite ſeparations, or manifeſt themſelves by unexpected operations when they meet with bodies fit to act on.

An ingenious goldſmith of my accquaintance, complain'd to me, that frequently buying parcels of gold, brought in ſmall pieces, or ſandy corpuſcles, from *Guinea*; tho' he found it upon all trials to be true gold, yet it was ſo very pale, that few but expert goldſmiths wou'd meddle with it; ſo that he was ſometimes reduc'd to melt it with very high colour'd gold, or to heighten its tincture with that of copper. And Monſieur *Flacourt*, govenor of the *French* plantation in *Madagaſcar*, ſpeaking, in his hiſtory of that iſland, of the metals there, ſays, "the inhabi-"tants have a gold of a different nature from that in *Europe*;" and adds, "that this gold is pale, and not worth above fifty ſhillings an ounce;" and farther, "that the negroes affirm there are many mines of it in the "country, where it was formerly dug; that there are three ſorts there-"of, differing in fineneſs from each other;" and, what is moſt remarkable, "that *Malacaſſean* gold, as they call it, is almoſt as eaſily melted as lead;"

lead;" whilſt the fine gold we deal with, requires vehement fires and borax to facilitate its fuſion.

Upon viſiting ſome mines of lead, and other metals, I found a great difference, diſcernible even to the eye, betwixt the ſeveral ores; for inſtance, I obſerv'd ſome lead-ore ſo like ſteel, that the workmen call it ſteel-ore; which being of a more difficult fuſion than ordinary, they mix with other ore, by them call'd firm-ore, when they commit it to the furnace. I likewiſe took notice of an ore, which, for its aptneſs to vitrify, and ſerve the potters to glaze their veſſels, the miners call pottern-ore, and ſell it dearer than other ore, from which it viſibly differs, and, as the workmen affirm, in many other qualities; yet all theſe ores, after fuſion, paſs indifferently under the name and notion of lead. No wonder, then, that curious enquirers find a great variation herein, I lately caus'd ſome lead-ore to be tried, which being the moſt promiſing I ever ſaw, made me ſuppoſe it might contain ſome conſiderable quantity of ſilver; but tho' it prov'd ſo rich in lead as to yield after the rate of ſeventy pound in the hundred, yet one of the moſt expert artiſts in *Europe* cou'd not extract one grain of ſilver out of it; tho' the lead of very many mines, being ſkilfully treated, will leave a proportion of pure ſilver upon the teſt. This quantity of ſilver, indeed, is not conſiderable enough to make ſuch mines as yield that lead paſs for ſilver mines; yet ſuch mines as are look'd upon but as lead-mines by the metalliſt, will appear to be mix'd ones to the naturaliſt; who may meet with ſeveral experiments wherein ſo little ſilver will make their lead operate differently from that of ores wholly deſtitute of ſilver.

The ſame differences might, probably, be found in the ores of other metals, if they were purpoſely and ſkilfully examined. A very experienced perſon in theſe affairs, was lately very deſirous I ſhou'd procure him ſome tin-ore; alledging, that he had met with a ſort, which, after a long digeſtion in lixiviate liquors, afforded him a very conſiderable proportion of the richer metals; ſo that having a large quantity of that ore, and finding the experiment on it to ſucceed conſtantly, he promis'd himſelf an eſtate from it; but when that ſtock of ore was ſpent, the next that he procured, tho' carefully managed as the former, was wholly unprofitable. And having once bought a parcel of block-tin, as the tradeſmen call that which is moſt pure and unwrought, I was deſirous to try if I cou'd not make a menſtruum to diſſolve it, as *Aqua fortis* diſſolves ſilver, and *Aqua regia* gold; becauſe chymiſts complain, that tho' they have a menſtruum or two that will diſſolve crude tin, yet they want one to keep it diſſolv'd; and not, like *Aqua fortis*, let it fall into a calx. Such a liquor being obtain'd, we evaporated a ſolution of that tin; and ſetting it to ſhoot, found, to our wonder, that the cryſtals it afforded were not at all like any kind of vitriol, but, broad, flat, and exceeding thin, like thoſe of ſilver: examining them alſo by the tongue, we found not that they had any ſuch taſte as the calx of tin, made in ſpirit of vinegar; but ſuch an exceſſive bitterneſs as may be met with in the cryſtals of ſilver, made with

Aqua

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Aqua Fortis. Finding this farther reſemblance betwixt the ſalts of theſe two metals, that both of them preſently dyed the nails and ſkin with a black that cou'd not ſoon be waſh'd off; we ſhou'd have ſuſpected, that the menſtruum had exalted this metal into an affinity with ſilver, had we not afterwards proſecuted the ſame trial with the ſame menſtruum, and another parcel of block-tin, and found, that tho' this metal was bought very ſoon after the other, and at the ſame place, the former ſucceſs proceeded from our having lighted upon the lump of tin that was of a peculiar nature.

I remember, alſo, that a friend of mine found, in his own land, a parcel of ore, which ſeem'd to me to be copper-ore; and, indeed, it did, after fuſion, yield a very good copper: but the perſons, to whom he committed the examination of the mine, being very inquiſitive, and extraordinary ſkilful, found in that ore, beſides the copper, a conſiderable quantity of ſilver; and in that ſilver, a conſiderable proportion of gold.

That great chymiſt *Baſil Valentine*, ſpeaking of antimony, tells us, "there are ſeveral kinds of it, and eſpecially two; the one more mercurial, and of a golden property, manifeſt by the ſhining ſtreaks "it abounds with; the other more full of ſulphur, but wanting the golden nature that enriches the former;" and adds, "there is ſuch a "different goodneſs betwixt the ſeveral ſorts of this drug, as betwixt "the ſeveral ſorts of fleſh or fiſh; which, tho' agreeing in name and "general nature, exceedingly differ in point of excellence." And, indeed, I have found a viſible difference betwixt the ſeveral ſorts of antimony. An excellent chymiſt ſhew'd me a parcel of antimony as a rarity, upon account of the variouſly colour'd ſulphur wherewith it was conſpicuouſly enrich'd; and ſoon after employ'd it to make butter of antimony; but tho' he was very expert in that kind of diſtillation, yet inſtead of the liquor he expected, upon the approach of a gentle fire, he found the neck and body of his retort lined with an antimonial cinnabar; at which being ſurpriz'd, he withdrew his fire till he had accquainted me with the accident; and I ſaw the cinnabar in the unbroken retort, tho' it ſeldom riſes till after the butter of antimony is come over, and the remaining matter be urged with a vehement fire. And to the undiſcern'd difference of antimonies we may, ſometimes, aſcribe that contingency frequently obſerv'd in making antimonial cinnabar.

And, perhaps, it is from ſome diverſity either in antimonies or irons, that eminent chymiſts have often fail'd in their endeavours to make the ſtarry regulus of them: whence many artiſts vainly imagine a certain reſpect to times and conſtellations requiſite to produce it. An induſtrious acquaintance of ours, working on antimony of a peculiar nature, and making a regulus of it, alone, in the common way, found, to his ſurprize, his regulus adorned with a more conſpicuous ſtar than ever I had ſeen in ſtellate reguluſſes of antimony and iron; yet I dare not be confident that this depended wholly upon the peculiar nature of that antimony, becauſe my own laboratory has, ſince that time, afforded me ſeveral

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veral ſuch parcles of regulus; which, tho' made of antimony that ſeem'd more rich than ordinary in ſulphur; yet as it did not conſtantly afford a ſtarry regulus, tho' order'd by the ſame perſon, and as near as poſſible after the ſame manner, it does not clearly appear whether the different event of the ſeveral trials proceeded from the peculiar nature of this or that antimony, or from ſome odd and ſcarce diſcoverable circumſtance in the management of the operation.

A conſiderable difference is obſervable in ſeveral other minerals, as well as antimony. I was lately preſented with a piece of mineral which ſeem'd to be an ordinary worthleſs marcaſite; yet a *Dutch* merchant, a ſkilful mineraliſt, its poſſeſſor, was very induſtrious to procure a large quantity thereof; having in ſome of it found a conſiderable proportion of pure gold. And the gentleman, whoſe copper-ore I formerly mention'd, digging for more of it, lately found a quantity of red earth, which by knowing mineraliſts was gueſs'd to be only bole; but being melted with *Regulus Martis ſtellatus*, by a ſkilful trier of metals, it many times recompens'd the examiner's curioſity, by affording him many grains of fine gold. And tho' I cannot ſay, whether this gold proceeded from the bole, or the regulus; it may ſerve for an inſtance, that ſome bodies, which paſs, without diſpute, for minerals of a preciſe nature, may have lurking in them ſubſtances of quite another kind; which may manifeſt themſelves in ſome particular experiments, tho' not in others.

Talc, uſually employ'd in coſmetics, is of ſo very difficult calcination, that eminent chymiſts have look'd on all calces of talcs as counterfeit. And, indeed, we have not calcined *Venetian* talc, without allowing a length of time, and a violent heat to the operation. But among many ſorts of *Engliſh* talc, there is one which a moderate fire will, in leſs than an hour, reduce to a ſnow-white calx: of which I have ſeen a parcel. And I lately met with another ſort of *Engliſh* talc, which I cou'd ſuddenly calcine, even with the flame of a candle. And a friend of mine aſſures me, that out of a *German* talc he met with, he, by digeſting it in a ſtrong ſolution of alkaline ſpirits, ſeparated a conſiderable quantity of good gold; and might have made it a very gainful experiment, if all the talc growing in the ſame place had been equally rich with that. The like has been affirm'd to me by a gentleman of eminence, who, from a certain talc, which he had out of *Norway*, once drew a tolerable proportion of very fine gold: and tho' ſome have been pleas'd to laugh at all attempts of ſeparating any thing from any kind of talc, yet ſome parcels of that mineral afford a rich tincture, for ought I know, of a golden nature. For I have met with a kind of darkiſh colour'd talc, which, when caſt only into *Aqua regis*, the menſtruum manifeſtly work'd upon it, and diſſolv'd its colour'd parts in ſuch plenty, that the filter'd ſolution paſs'd without ſuſpicion, among many eminent naturaliſts for a fair ſolution of gold. *Paracelſus* reckons four kinds of talc; red, white, black, and yellow, and, perhaps, each of theſe colours comprizes ſeveral kinds of the mineral; and, therefore, after having mention'd a great

variety

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variety of marcaſites, ſtones, and other minerals, he adds, "there lie many "more in the bowels of the earth, which are unknown both to me and others, "but may in tract of time be diſcover'd."

'Tis vulgarly known, that there is a great difference between vitriols of the ſame metal; and as for thoſe vitriol-ſtones, whereof we in *England* make our vitriol; I have ſeen at our chief copperas-works ſo great a variety of them, that I could ſcarce believe the workmen, when they affirm'd them to be all copperas-ſtones: and I think it very likely, that ſome of them contain other mineral ſubſtances beſides vitriol; and poſſibly the ſaline parts of thoſe ſtones, upon their ſolution by the rain, may work on other ſubſtances formerly coagulated with them, and thereby communicate to ſome parcels of the vitriol, qualities not eſſential to the nature of that ſubſtance, nor ordinarily belonging to it.

That there is, alſo, a difference betwixt thoſe bodies which paſs under the name of common ſalt, muſt be obvious to every chymiſt, who hath made accurate trials upon that ſubſtance. And for thoſe concretes that paſs for ſalt-petre, there is, probably, no ſmall diſparity among them, beſides the obvious difference betwixt good *Engliſh* nitre, and that which is brought from *Barbary*. Thoſe who uſe both good *European* and good *Eaſt-Indian* ſalt-petre, aſſure me, they find a difference betwixt them, and give the preference to the latter: and indeed I have often thought I diſcern'd a conſiderable difference in the operations of ſeveral kinds of ſalt-petre, even after purification. And, probably that ſort of it, which an ingenious man of my acquaintance ſometimes makes, near *London*, chiefly out of ſea-ſalt, has ſome different qualities from that which is drawn in the common way from earth. Indeed, ſalt-petre being but a kind of *ſal terræ*, generated in parcels of the earth, very differently qualified, may, probably, receive ſeveral qualities from the ſoil wherein it grows; though theſe qualities lie conceal'd and unſuſpected, under the common external appearance of nitre. A very ingenious gentleman aſſured me, that one of the moſt eminent of our *London* phyſicians, had an excellent ſecret, to employ in ſome of his choice remedies, that peculiar ſalt-petre which he drew out of the earth, dug up in church-yards. A gentleman alſo aſſures me, he has, in *England*, met with a ſandy earth, that turns wood into ſtone, tho' there be no petrifying ſpring near the place; and this it does in a better manner than any water I have yet ſeen. And the like differences would, probably, be taken notice of in other mineral bodies, if mens prepoſſeſſions did not make them aſcribe the variations they meet with in their experiments, rather to any other cauſe, than the unſuſpected difference of the materials employ'd in them.

Nor is it only among mineral bodies of the ſame name, that ſuch a diverſity is to be found; 'tis very probable, that a greater diſparity may be diſcover'd, both among vegetables and animals, if narrowly examined, which are reputed of the ſame nature, than hath been yet taken notice of. Botaniſts, indeed, have ſhewn a commendable curioſity in ſubdividing plants of the ſame denomination; and few naturaliſts are ignorant, that there are, for inſtance, many ſorts of roſes, and of apples, which differ

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widely betwixt themſelves; as the red roſe, and the white, the crab, the pippin, and the pearmain. But, beſides theſe differences, which are obvious enough to be regiſter'd by botanic authors, there may be more undiſcern'd ones betwixt the individuals of the ſame ultimate ſubdiviſion of plants, ariſing from the temperature of the air; which makes, for example, ſena growing in *England* to differ much from that of *Alexandria*; and from the nature of the ſoil, as appears by the change produced in wild ſimples tranſplanted into gardens, and many other cauſes. We often ſee, that one roſe differs from another of the ſame kind, and one pearmain from another pearmain. To which we may add, that the upper cruſt, or ſurface of the earth, being impregnated with ſubterraneal exhalations of ſeveral ſorts, and temper'd with variety of juices, it's very poſſible that ſome particular plant may attract ſuch a juice out of a determinate ſpot of ground, as to give it exotic qualities, and make it differ even from the neighbouring plants of the ſame kind. Thus, I remember, I met with, in *Switzerland*, a ſort of very heady wine, that otherwiſe ſeem'd to be ſack, tho' it grew amongſt the mountains of the country; but I could not believe it, 'till they aſſured me, that it received its inebriating quality, with the reſt of thoſe that remarkably diſtinguiſh'd it from the other wine of thoſe parts, by growing on a little ſpot of ground, whoſe entrails abounded with ſulphur. And ſince I have mention'd wine, I may further remark what a great change is made in that liquor, when, upon the receſs of the ſpirits, and more volatile ſulphureous parts, it degenerates into vinegar; whilſt little diminution of quantity, or any other alteration, appears upon this change. And tho' this change is familiar to us, yet who knows what others may be produced in bodies, with whoſe alterations we are unacquainted; whilſt the eye, which is often the only ſenſe employ'd about judging of them, diſcerns no difference? Thus, we may daily obſerve the ſuperannuated ſeeds of plants, after having been long kept beyond their due time, loſe all their germinating power; tho' they retain all their obvious qualities. Urine is much uſed by dyers, and ſeveral other tradeſmen, who indifferently employ it, without examining whether it be rich in ſalt, and how long it hath been kept; tho' chymiſts, who frequently have occaſion to diſtil it in large quantities, aſſure me, that they find a notable difference therein; that of healthy young men, abounding much more with volatile ſalt, than that of ſickly or aged perſons. They ſay, alſo, that the urine of ſuch as drink wine freely, is much fuller of ſpirituous and active parts, than that of thoſe who drink only beer or water. And tradeſmen, who boil their ſeveral commodities indifferently in any urine, may thereby ſometimes commit conſiderable errors: for freſh urine, wherein the ſaline parts are entangled among the reſt, will endure to be boiled above one half or two thirds away, without loſing its volatile ſalt and ſpirits; whilſt that which has been kept for ſeveral weeks, is liable to a putrefaction, whence the component parts fall aſunder; and the ſaline ones, extricating themſelves from the reſt, will, upon a very gentle heat, evaporate, and leave a phlegmatic, unactive liquor behind them. Having cauſed ſome urine to be buried in earthen veſſels in a dunghill, to putrefy for five or

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ſix weeks, I was kept from employing it 'till it had lain there between four and five months; and obſerving, when I caus'd it to be taken out, that the covers of the veſſels had not been well luted on, and were, beſides, in ſome places, crack'd; I ſuſpected that the heat of the dung had not only looſen'd the ſaline parts of the liquor, but driven them away; and accordingly, by diſtilling it with a very gentle heat, and in a very high cucurbit, we obtain'd, inſtead of an active and ſaline ſpirit, a languid and nauſeous phlegm. And how great odds there may be betwixt ſome experiments, made with new and putrefied urine, may be eaſily conceiv'd by him who knows what effect ſalts have in the production of colours; and is acquainted with their efficacy in thoſe other mechanical experiments, wherein urine is employ'd.

Thirdly, there is a great difference to be found among many things pre- *And in their Preparations.*
pared by art, that bear the ſame general name; which may proceed from what we have already obſerved, in the materials, of which ſuch bodies are compoſed, or from the means uſed in preparing them. But we ſhall, at preſent, mention only two ſorts of factitious bodies; ſuch as are not ſufficiently purified, and ſuch as are purified too much.

It is very certain, that many chymical experiments, deliver'd by ſober authors, have been judg'd falſe, only becauſe the menſtrua, or other materials employ'd in the unſucceſsful trials, were not as highly rectified, or, otherwiſe, as exquiſitely depurated, as thoſe that were uſed by the original experimentor; ſo that the fault of a bad menſtruum, is often injuriouſly imputed to an excellent artiſt. That experienc'd chymiſt *Van Helmont*, endeavours to explain the manner wherein the *calculus humanus* is generated, by the coagulation immediately enſuing upon the mixture of the two volatile ſpirits of urine, and of wine. This noble experiment has, by many, been unſucceſsfully tried, and therefore by them condemned as a chymical fiction; and the firſt, and, I think, the ſecond time we attempted to make that coagulum, we found nothing of what we expected: but at length, thinking it poſſible that the ſpirits we employ'd had not been ſufficiently exalted, we dephlegm'd ſome by more frequent and tedious rectifications; and thence, by more accurate trials, were ſatisfied that *Van Helmont* had not miſinform'd us. So likewiſe the ſame author, extolling the tincture or ſolution of amber, made with ſpirit of wine, as a noble ſtomachic, cephalic, *&c.* many phyſicians and chymiſts have attempted to prepare this tincture, with ſuch bad ſucceſs, that they declare, *Helmont* either deliver'd what was falſe, or conceal'd ſome conſiderable circumſtance of the proceſs. But having digeſted well-dephlegmed ſpirit of wine upon high-colour'd and very finely powder'd amber, and placed them in a very gentle heat; we have, ſeveral times, obtain'd a true tincture of amber, diſcernible both by its ſmell and taſte. And, to ſhew that this colour proceeded from a real ſolution of the more ſubtile parts of the amber, we pour'd ſome drops of it into water; when, the ſpirit of wine ſuddenly diffuſing itſelf; the diſſolv'd amber was plainly diſcernible, ſwimming like a thin film upon the ſurface of the liquor, whence it gradually exhaled into the air.

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There may, likewiſe, as we have tried from pure ſalt of tartar, be drawn, with ſpirit of wine, a pretty high tincture, and of a remarkable taſte; but upon lately trying to draw this tincture with ſpirit of urine, which, unknown to me, was much too weak for that purpoſe, I found that after I had kept the glaſs a while in digeſtion, the ſalt of tartar had drawn to itſelf, and imbibed the aqueous particles of the ſpirit; and being thereby, in part, diſſolv'd into a liquor, the ſubſiding ſalt was, by the interpoſition thereof, protected from the action of the ſpirit of wine; which, being thus dephlegm'd, would not mix with the ſaline liquor, but ſwam entirely above it. This I ſhall add, in general, that the *German* chymiſts are commonly ſo accurate in the rectification of their ſpirit of wine, that, in *England*, where we are leſs careful in that particular, it is common, for thoſe experiments of theirs, to be unſucceſsfully try'd, wherein the alcohol of wine is requiſite.

And it is not only in menſtruums, but in many other bodies, that the want of an exquiſite depuration may produce a variety of events in experiments: as, for inſtance, it has been complain'd of by ſober men, that their preparations of ſilver, tho' never ſo carefully made, have been apt to prove violently emetic; tho' we have not obſerv'd a well-prepar'd medicine of duly refined ſilver to work by vomit, even in women and children, but by ſtool, or urine. We cannot, however, wonder at the violent operation of medicines made with ordinary ſilver; for not only that of coin is allay'd with about a twelfth part of copper; but even that which is commonly, at a great rate, ſold for refined ſilver, is not often ſufficiently freed from its copper; as I lately manifeſted in the preſence of one of our moſt eminent refiners, by diſſolving ſome of his pureſt ſilver in his own *Aqua fortis*; for the greenneſs of the ſolution quickly betray'd the baſer metal: and no wonder, for I have ſeldom ſeen our chiefeſt refiners blow off from their ſilver, upon the teſt, above half its weight of lead; whilſt we think not our ſilver ſufficiently refined, 'till it has been freed from five or ſix times its weight thereof; and then it has afforded a ſolution as clear as water, with only, now and then, a ſcarce diſcernible tendency towards ſky-colour.

Now, that ill effects, by the mixture of copper, may be produced in ſuch medicines, as ought to be of pure ſilver, the violent emetic qualities of the former will ſcarce ſuffer us to doubt. And, as in mens bodies, ſo in other ſubjects, thoſe experiments may eaſily fail the artiſt's expectation, when he hopes to perform, by a mixture of thoſe two metals, that which requires pure ſilver alone. And as ſilver, ſo gold is very often employ'd for pure, when 'tis otherwiſe: the foliated gold, commonly ſold here in *England*, how fine ſoever reputed, is not altogether free from the pollutions of other metals; for our gold-beaters, tho' for their own profit they uſe the fineſt gold they can get, yet ſcruple not to employ coin'd gold; and this the mint-maſters allay with copper, or ſilver, to make it ſtiff, and leſs ſubject to waſte by attrition. And as for thoſe goldſmiths, and chymiſts, who think their gold moſt exquiſitely refined, when they have blown from it, on the teſt, a due proportion of lead, they may therein be ſometimes miſtaken;

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miſtaken; for tho' the lead may carry away with it all the copper that debaſes the gold, yet the gold does not always, after this, remain free from ſilver: nay, the moſt ſkilful refiner that I ever knew, hath, ſeveral times, affirm'd to me, that after cupelling fine gold, with lead, the gold has retain'd, and protected from the fire, a proportion of ſilver that lay lurking in the lead, and was afterwards ſeparated from the gold by *Aqua fortis*, tho' in ſo ſmall a quantity, that the experiment was not gainful.

But as many experiments ſucceed not, becauſe the menſtrua employ'd about them were not pure enough; ſo ſome miſcarry, becauſe ſuch menſtrua are too exactly depurated: for it is not ſo much the purity of liquors in their kind, as their fitneſs for the particular purpoſe to which they are deſign'd, that is to be principally regarded in experiments. For inſtance, we have ſometimes made pieces of paper, and linen, appear all on a flame, without either burning, ſinging, or ſo much as diſcolouring them. This is perform'd, by moiſtning the paper or linen throughly in weak ſpirit of wine, and then bringing them to the flame of a candle, by which the ſpirituous parts of the liquor will be fired, and burn a pretty while, without harming them; but if the experiment be tried with exquiſitely rectified ſpirit of wine, it will not ſucceed: however, the flame of ſpirit of wine is ſo hot, that I have, in lamp-furnaces, employ'd it inſtead of oil, and with the ſame flame, have melted leaf-gold. The reaſon, therefore, why paper is not burned by the flame that plays about it, ſeems to be, that the aqueous part of the ſpirit of wine being imbibed thereby, keeps it ſo moiſt, that the flame of the ſulphureous parts of the ſame ſpirit cannot faſten to it; and, accordingly, when the flame ceaſes, the paper remains moiſt. On the other hand, having purpoſely plung'd paper into dephlegm'd ſpirit of wine, it was very readily kindled, and burn'd by the flame thereof. And one of our beſt ways to try the purity of ſpirit of wine, is grounded on this very ſuppoſition: for dipping a cotton wiek therein, and ſetting it on fire, if the flame faſten on the wiek, it is a ſign the ſpirit is pure; but if it does not, we conclude it to be not ſufficiently dephlegm'd. Some artiſts, likewiſe, obſerve, that *Aqua fortis* will work more readily on lead, for being allay'd with water. I have uſed an *Aqua fortis* ſo ſtrong, that it would not well diſſolve ſilver, unleſs firſt diluted with fair water. And I have had an unwelcome proof, that liquors may, by too exquiſite a depuration, be made unfit for ſome purpoſes. For having, to gratify ſome friends, made a certain menſtruum, wherewith we had perform'd ſurprizing things upon gold, we took care, againſt the time of their exhibition, to ſeparate it from whatever was of an aqueous or earthy nature, more exactly than ever before. But coming to make uſe of this ſort of menſtruum, we found, that inſtead of performing its operation upon gold better than uſual, we could do nothing at all with it: for it would not now, even by heat, be brought to touch gold, tho' it uſed, unaſſiſted, to diſſolve it. But having, for trial-ſake, taken a little of this numerical parcel of liquor, before it was ſo carefully rectify'd, it diſſolv'd crude gold, as well as we had reaſon to expect. And it deſerves to be conſider'd, whether or no, in the extraction of the tinctures of ſeveral bodies,

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bodies, chymiſts do not put themſelves to a needleſs and prejudicial trouble by refuſing to employ any other ſpirit of wine, than that which is highly rectified: for, tho' in many ſubſtances, the parts deſired by the artiſt being ſulphureous, the menſtruum is the better for an exquiſite dephlegmation; yet in ſeveral others, the uſeful and efficacious parts are the ſaline, which make them more freely impregnate ſuch liquors, as have ſome aqueous mix'd with their ſulphureous parts.

Unregarded circumſtances may prevent the ſucceſs of experiments.

Thus much for the manner wherein experiments may miſcarry, upon account of their materials. Let us next conſider the contingencies whereto they are obnoxious, from circumſtances that are either unobvious, or ſcarce diſcernible, 'till the trial is over. A phyſician of unqueſtionable veracity aſſured me, that, as upon taking a journey, he lent his laboratory to a friend in *Holland*, wherein, among other things, was great ſtore of *Aqua fortis* of ſeveral compoſitions, which he had made to employ about his ſcarlet dye; his friend ſoon after ſent him word, that by digeſting gold with an *Aqua fortis*, he had ſeparated the tincture, or yellow ſulphur, from it, and made it volatile; the remaining body growing white; and that with this golden tincture he had turned ſilver into very perfect gold, with conſiderable profit. Upon this news, the doctor preſently return'd to his laboratory, and did, himſelf, with the ſame *Aqua fortis*, ſeveral times, draw a volatile tincture of gold, which turn'd ſilver into true gold. He farther affirm'd, that out of an ounce of gold, he thus drew as much ſulphur, as ſufficed to convert an ounce and a half of ſilver into that nobleſt of metals. This I am the more diſpoſed to believe, becauſe I have found, that a yellow ſubſtance, or tincture, is obtainable from gold; and, becauſe I am tempted to think, that ſilver may have in it a ſulphur capable of being advanced, by maturation, into a golden one*. For I have been aſſured, by men very experienc'd in metalline affairs, that they have ſeen, ſometimes by corroſive liquors, and ſometimes by the operation of common ſulphur, eſpecially well open'd, and aſſociated with fit ſalts, ſilver to afford ſome grains of very pure gold. But the doctor found himſelf much miſtaken in his hopes of growing rich by this experiment; for a while after, endeavouring to make it again, it ſucceeded not; which he aſcribes to a defect in the *Aqua fortis*, and therefore has attempted the ſame work afreſh. But ſince all his trials have been hitherto fruitleſs, 'tis not improbable, that the diſappointment proceeded from ſome other more abſtruſe cauſe; for we find ſuch accidents have ſometimes befallen artiſts irreparably. *Glauber* tells us of ſeveral ways, by which he made gold once, but could not do it again. The prince of *Mirandula*, in his treatiſe *de Auro*, tells us of ſeveral perſons, whom he knew had the like ſucceſs in preparing both gold and ſilver. And I could inſtance in my own acquaintance, thoſe who, having once or twice made *Luna fixa*, (which, wanting only the tincture of gold, abides the trial of *Aqua fortis*, &c.) or ſome other gainful experiment, have ſince, in vain,

* M. *Homberg* declares, he has actually converted ſilver into gold, by heat. See the *French Memoirs* for the year 1709, p. 139—143.

attempt-

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attempted the like; and yet cannot be prevailed with to deſiſt from proſecuting their uncertain hopes. And the moſt experienc'd mineraliſt I ever met with, has aſſured me, he ſhould quickly grow rich, could he but conſtantly perform what he has ſeveral times perform'd *. It may be very ſerviceable to know, that many experiments ſucceed, when made with ſmall quantities of matter, which fail in greater: ſeveral projectors, eſpecially chymiſts, have very dearly bought the knowledge of this truth For it often happens, that an unwieldy quantity of matter, cannot be expos'd, in all its parts, to a juſt degree of fire, or otherwiſe ſo well manag'd, as a leſs: hence many have ruin'd themſelves, by obſtinately attempting to make even real experiments more gainful.

It is deliver'd by the Lord *Verulam*, and other naturaliſts, that if a roſe-buſh be carefully cut, as ſoon as it has done bearing in the ſummer, it will again bear roſes in the autumn. Of this, many have made unſucceſsful trials, and thereupon report the Affirmation to be falſe; yet, I am very apt to think, that my Lord was encouraged by experience, to write as he did. For, having been particularly ſollicitous about the experiment, I find by the relation, both of my own, and other experienc'd gardeners, that this way of procuring autumnal roſes, will, in moſt roſe-buſhes, commonly fail, but ſucceed in ſome that are good bearers; and accordingly, having this ſummer made trial of it, I find, that a row of buſhes, cut in *June*, by far the greater number promiſe no autumnal roſes; but one that hath manifeſted itſelf to be of a vigorous and prolific nature, is, at this preſent, indifferently well ſtored with thoſe of the damaſk-kind. There may, alſo, be a miſtake in the ſpecies of roſes; for experienc'd gardeners inform me, that the muſk-roſe will, if it be a luſty plant, bear flowers in autumn, without cutting: and therefore, that may unjuſtly be aſcribed to art, which is the bare production of nature. Cinnamon roſe-buſhes thrive ſo much better by cutting, than ſeveral other ſorts, that I remember, this laſt ſpring, my gardener having, about the middle of *April*, cut many of them in my garden, I ſaw about the middle of *June*, many of the ſame buſhes, plentifully adorn'd both with buds and blown flowers.

An uncertainty, like this, has been likewiſe obſerv'd, in attempting to produce different ſorts of fruit from the ſame tree; however, we have lately ſeen various ſorts of pears, fed by the ſame plant; and three and twenty ſorts of apple-grafts flouriſhing upon the ſame old ſtock; moſt of which were adorned with fruit. Nay, and tho' the fruits be not of the ſame denomination, yet, if they be of kin in nature, they may, very poſſibly, be brought to grow on the ſame tree; for we lately gather'd both apricocks and plumbs from the ſame tree, and expect other ſorts of ſtone-fruit from it. But, for fruits of very different natures, to be proſperouſly nouriſhed by the ſame ſtock, is ſo difficult, that we can only reckon it among contingent experiments: for tho' both *Pliny* and *Baptiſta Porta*, relate their having ſeen an

* To this general Purpoſe, we may obſerve with M. *Homberg*, that, in certain circumſtances, *Aqua regia* will diſſolve Silver. See the *French Memoirs* for the year 1706, *p.* 128.

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example of it; and, tho the great Dr. *Ward* assures me, he has particularly taken notice of pears growing upon an apple-tree; yet, certainly this experiment has been, for the most part, but very unprosperously attempted; nor have I yet ever seen it succeed, tho try'd with very great care and industry. And in the same garden, where I gathered the apricocks and plumbs above-mentioned, I saw the ciens of a pear-tree, so skilfully grafted upon an apple-stock, that it flourish'd with blossoms in the spring; and gave me great hopes, that it would bear fruit the last summer; but it has baulk'd my expectation: as many other plants, so grafted in the same garden, have, for many years, deluded the skilful master of it; who assures me, that tho several of them did, for some years successively, afford promising blossoms, yet they all decay'd without yielding any fruit. This seems somewhat strange, because we have gather'd pears from a shoot affirmed to have been grafted upon a quince-tree; and *Kircher* tells us, "'tis found by "experience, that a peach grafted upon a mulberry, will prosper and bear "fruit." And we daily see, that as little as a white-thorn and a pear-tree seem allied, a cien of the latter will prosper very well, grafted upon the stock of the former.

To contingent experiments, we may refer what is deliver'd by those, who affirm, that if a lixivium made of the fixed salt of a Plant, be frozen; there will appear in the ice the image of the same plant: for we have frequently made this experiment without the promised success; and neither a solution of the salt of wormwood in fair water, nor the decoction of that plant, would, when frozen, exhibit any thing like its figure in the ice. 'Tis common, indeed, to find these liquors, solutions of sugar, salt, &c. frozen into odd figures; and even common water will do the same: which need not be wonder'd at; since it glides thro' earths abounding in saline particles of particular natures: whence, perhaps, it is, that dyers find some waters very fit, and others very unfit, for their purposes. Yet, because two or three sober writers seriously relate some stories, of this nature, upon their own observation, I am content to rank their experiments rather among the contingent, than the absolutely false ones: for it is possible, that among the many figures which frozen liquors sometimes put on, there may be something so like a particular plant, that, view'd with a favourable eye, it may seem to exhibit the picture of the calcined vegetable. Setting a fine green solution of good verdigrease to freeze, in snow and salt, that containing much of the saline parts of the grapes, coagulated upon the copper they corroded; I obtain'd an ice of the same colour, wherein appeared several liitle figures, so like to vines, that we were somewhat surpriz'd at the experiment. And what encreas'd our wonder, was, that, another part of the same solution frozen in a different vial by the bare cold of the air, afforded us an ice angularly figur'd, but not at all like that made by the application of snow and salt. And having, for further satisfaction, suffer'd that ice, wherein the vines appear'd, to thaw of itself, and then to freeze a second time in the same vial, after the same manner; we could not discern in the second ice, any thing like that we had admired in the first. And in wine and vinegar, as much

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as thoſe liquors partake of the nature of the vine, we never, after congelation, obſerv'd any peculiar reſemblance thereto.

The experiment of burning with ice, as with a glaſs-lens, tho' preſcribed without any notice taken of the difficulty in it, yet, both we and others, who have induſtriouſly try'd it, meet with ſuch diſcouraging circumſtances therein, eſpecially from the unequal texture of moſt ice, that it may well be referr'd to thoſe, whoſe conſtant ſucceſs is not to be rely'd on. In the trade of dying, there is ſcarce any ingredient of ſo great and general uſe, as woad; for tho', of itſelf, it dyes but a blue, it is uſed to prepare the cloth for green, and many other ſadder colours, when they are deſign'd to be permanent, and not to fade: but in boiling of it, to make it yield, or ſtrike its colour, there are ſome critical times, and other circumſtances, to be obſerved; an eaſy miſtake wherein often defeats the dyer's expectation, to his very great loſs; which, ſometimes, he knows not to what he ſhould impute it: and of this, I have heard ſeveral of them complain. And, therefore, many of our leſs expert dyers, to avoid thoſe hazards, leave off the uſe of woad, tho' growing plentifully in *England*; and, inſtead of it, employ indigo, tho' it coſt them dearer, as being brought hither from *Spain*, *Barbadoes*, or the *Eaſt-Indies*.

Our *London* refiners, when to part ſilver and copper, they diſſolve the mixture of them in *Aqua fortis*, afterwards greatly dilute the ſaturated menſtruum with fair water, and then with copper-plates, ſtrike down the ſilver. But becauſe much copper thus remains in the menſtruum; that the liquor may be improv'd to the beſt advantage, they pour it upon what they call whiting; that is, white chalk or clay, finely powder'd, cleans'd, and made up into balls, wherewith the tinged parts incorporating themſelves, will, in ſome hours, conſtitute a ſort of verditer fit for painters, *&c.* leaving the reſt of the menſtruum an indifferently clear liquor; whence they afterwards, by boiling, obtain a kind of ſalt-petre, fit, with the addition of vitriol, to yield them a new *Aqua fortis*. But ſometimes the refiners cannot make this verditer for a great while together, yet know not whence their inability proceeds. Of this contingency, I lately heard one of the moſt eminent of them complain; tho', for his part, he had found a remedy for it: which is, to warm the menſtruum well before it be poured on the whiting, whereon the tinged parts would then faſten, tho' not when poured on cold.

One of the overſeers of the chief copperas-works we have in *England*, aſſured me, that by the miſtake or neglect of a circumſtance, in point of time, they had frequently loſt ſome thouſand pounds weight of vitriol at a time; which would degenerate into an unctuous ſubſtance, not to be reduced into good vitriol again, unleſs by the tedious way of throwing it abroad, and expoſing it, with the unprepared ſtones, to the rain and ſun, to be open'd a-new, and fitted to yield it, after the ſame manner with thoſe crude minerals.

Joſephus Acoſta, who diligently ſurvey'd the famous mines of *Peru*, and, for one who was not a chymiſt, has deliver'd many conſiderable and judicious obſervations about them, ſays, " it is ſtrange to ſee, not only the diffe-

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" rence betwixt the refining of metal by fire, and, without it, by quickſilver;
" but alſo, how ſome of theſe metals refined by the fire, will not melt, when
" that is blown with any artificial wind, but requires the natural air. The
" metal of the mines of *Porco*," ſays he, " is eaſily refined with bellows;
" whilſt that of the mines of *Potozi* cannot be fuſed with bellows; but only
" by the breath of their ſmall furnaces, built upon the ſides of mountains,
" directly where the wind lies: and tho' it be hard to aſſign a reaſon of this
" difference, yet the thing is certain, and confirm'd by long experience."

If any trade obliges the artificer thoroughly to underſtand the management of the materials employ'd therein, it is that of glaſs-making; yet, even in the moſt ordinary operations of this art, there happen, now and then, little accidents, which, tho' they know not well what to aſcribe to, are yet capable of hindring them from performing what they have done a thouſand times. An eminently ſkilful workman, whom I had purpoſely engaged to make ſome veſſels that required more than ordinary dexterity, was, lately, unable to make metal tolerably fit to be uſed; and therefore he deſired me to come again another day, when he would try to retrieve his misfortune. But, returning by appointment, his metal again prov'd unſerviceable; and inſtead of being colourleſs when cold, it ſeem'd ſtain'd with blue and yellow, and was, beſides, too brittle; ſo that it need be no ſuch wonder, if philoſophers and chymiſts, ſometimes miſs the expected event of an experiment but ſeldom try'd; ſince tradeſmen themſelves cannot always accompliſh what, if they were not able frequently to perform, they could not ſubſiſt.

It is affirmed by *Helmont*, and others, who treat of the *Lapides cancrorum*, that they grow within the ſkulls of craw-fiſhes; but I have known good anatomiſts complain, that they have there ſought them in vain; yet we have often taken thoſe ſtony concretions out of the heads of ſuch fiſh*. But paſſing lately thro' *Hungerford*, a town famous for craw-fiſh, we made diligent enquiry into their nature; and were there inform'd, that the concretions above-mentioned, are to be found in their heads, only about that ſeaſon of the year wherein they ſhift their ſhells; and that at other times, ſeveral perſons had in vain endeavour'd to obtain them. And, indeed, having at the laſt time of my being there, about the latter end of *June*, caus'd many of the larger ſort to be taken out of the water, we found thoſe little ſtones in the head of but one of them; tho' about a fortnight before, we had taken out of the uſual part of their heads, ſeveral ſuch concretions, as to magnitude and ſhape; but ſo ſoft, that we could eaſily cruſh them be-

* We are aſſured by Monſ. *Geoffroy*, from his own obſervation, that the ſtones taken out of the heads of craw-fiſh, belong not to the brain, but the ſtomach of the creature, which lies underneath; that they do not ſupply matter for a new ſhell, but are to be found after the ſhell is formed; that the animal, in changing its ſhell, changes alſo its ſtomach, and, perhaps, its inteſtines; that theſe ſtones appear not, but at the time of their annual change of ſhell, when they are weak, ſick, and ceaſe to feed; that afterwards, the ſtone is ſurrounded with a new ſtomach, and diminiſhes inſenſibly, 'till it entirely diſappears; and, laſtly, that theſe ſtones, with the membrane of the old ſtomach, ſerve to nouriſh the animal, during its ſickneſs, upon its change of ſhell. *Memoir. de l'Academ. Roy. A.* 1709. p. 409.

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twixt our fingers. And certainly, miſtakes in point of time, have greatly prejudiced the reputation of many truths. *Aſellius* ingenuouſly acknowledges, he had nearly miſs'd the diſcovery of the lacteal veins, becauſe, having at firſt ſuſpected thoſe unlook'd-for white veſſels, which he took notice of in the meſentery of a dog, diſſected alive, to be ſome irregular ramifications of nerves; he was much confirm'd in his conjecture, by the next dog he open'd: for taking him at an inconvenient time, after feeding, the ſlender veſſels he look'd for, being deſtitute of chyle, were not conſpicuous; ſo that he had loſt the benefit of his firſt lucky obſervation, had not his ſagacity led him to ſuſpect, that if a dog were plentifully fed, at a convenient diſtance of time before diſſection, the veſſels, ſwell'd with alimental juice, would be more diſcernible: and, in purſuance of this conjecture, he made that famous diſcovery of thoſe veins.

We may ſay, in the general, that ſuch circumſtances, as are very difficult to obſerve, or ſeem to be of no concern in an experiment, may yet, in many caſes, have a great influence in the event of it. If on either pole of a good arm'd load-ſtone, you gently draw the back of a knife, which has not before receiv'd any magnetic influence; you may obſerve, that if the point of the blade have, in this motion, paſſed from the equator of the ſtone towards its pole, it will attract one of the extremes of a librated magnetic needle: but if you take another knife, that has never been invigorated, and, upon the ſame pole of the load-ſtone, thruſt the back of it from thence towards its equator, the point of the knife will, by this bare difference of poſition in the blade, acquire ſo different a magnetic property, or polarity, from that which was given to the former knife, by the ſame pole of the load-ſtone, that it will not attract, but rather ſeem to repel that end of the magnetic needle which was attracted by the point of the other knife. This improbable experiment we have made, not only by paſſing ſlender irons upon the extremities of arm'd load-ſtones, the breadth of whoſe ſteel-caps may render it ſomewhat leſs ſtrange; but even by affrictions of ſuch irons upon the pole of a naked terella. But how far this ſurprizing obſervation inſinuates the operations of the load-ſtone, to be perform'd by ſtreams of ſmall particles, perpetually iſſuing out of one of its poles, that, after wheeling about, re-enter at the other, we ſhall not now examine; tho' this ſeems one of the moſt likely phenomena we have met with, to hint a probable magnetical hypotheſis. But hence it plainly appears, how great an influence a circumſtance, which none but a magnetic philoſopher would take notice of, may have on an experiment.

Artificers give very different tempers to ſteel, by holding it in the flame, or heat, for different minutes of time. I have a graver, ſaid to be of *Damaſco* ſteel, whoſe temper is ſuch, that I cannot let it down by any art; tho' one, who has had the opportunity of making more than ordinary enquiry into matters of this nature, aſſures me, he can eaſily ſoften this kind of ſteel, by only taking it off the fire at a certain juncture of time; differing from that obſerv'd in ſoftning the common gravers. And who knows, but that in many other experiments, ſeemingly deſpicable and unheeded circumſtances may be of great moment; tho',

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thro' want of particular obſervations, men have not generally taken notice of their importance.

Many planters have, with wonder, obſerv'd, that ſome grafts of cherry-trees, for example, have yielded fruit the ſame year wherein they were grafted; (as I have obſerved ſome plants to bear in the ſame quarter of the year) and others not 'till the year after their inſition; tho' neither in the goodneſs of the graft, nor in that of the ſtock, they had remark'd any diſparity, to which this difference could be aſcribed; and, therefore, the bearing, or not bearing of the ciens of a cherry-tree, the firſt year of its inſition, is, by them, look'd upon as a thing merely contingent. Yet, I am inform'd, by the trials of more than one of the moſt ſkilful and experienc'd grafters of theſe parts, that a man ſhall ſeldom fail of cherries from the graft, the ſame year in which the inſition is made, if he take care the graft be of a good kind, and have bloſſom-buds upon it; but if they were only leaf-buds, it will not bear 'till the ſecond ſeaſon. And to diſcern ſuch buds as are fit to produce bloſſoms, from ſuch as will diſplay themſelves only in leaves, is no difficult matter; the former ſort being more full, larger, and round than the latter, which alſo lie more flat and cloſe to the graft.

By the *Virgula divinatoria*, many mineraliſts pretend to diſcover the latent veins of metals. Some uſe a forked hazel, whoſe horns they hold by the ends, one in each hand: and others content themſelves with a hazel-rod of the ſame year's ſhoot, which they bind on to another ſtreight ſtick of any other wood; and walking ſoftly with it over thoſe places where they ſuſpect metals to be conceal'd, they ſay, that, if they paſs over a metalline vein, the wand will, by dipping there, diſcover it. And I know ſome who affirm, that by holding metals ſucceſſively in that hand where the rod is, it may be diſcover'd what determinate metal predominates in the vein; for that when the metal wherewith the mine chiefly abounds, is held in the ſame hand, the wand will manifeſtly bow more ſtrongly, than when it is held in conjunction with any other metal. What to determine, as to the truth of this experiment, I know not: for *Agricola* himſelf, after a long debate concerning it, tells us, that an honeſt metalliſt will not uſe this rod; and that, if he be ſkilful, he may do without it; "tho' indeed, ſays he, it "does afford ſome actual ſigns of veins." *Kircher* informs us, that, having exactly try'd the experiment with metals, he could not find it, in any meaſure, to ſucceed: and we ourſelves, having ſeveral times made trials of it in the preſence of the moſt confident aſſertors of its truth, could not be ſatisfied, that the wand did ſtand either to the metals placed under it, or to the metalline veins, when carry'd over mines whence metalline ore was at that very time digging out. But, on the other ſide, many eminent authors, and even our diligent country-man *Gabriel Plat*, aſcribes very much to this detecting wand; and many perſons, in other things very far from credulous, have, as eye-witneſſes, ſolemnly aſſerted the truth of the experiment to me. And one gentleman, who lives near the lead-mines in *Somerſetſhire*, leading me over thoſe parts of them where we knew there run metalline veins, made me take notice of the inclination of the wand when we paſs'd over

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over a vein of ore; and protested that the motion of his hand did not at all contribute to the inclination of it; but that sometimes, when he held it very fast, it would bend so strongly, as to break in his hand. And to convince me that he believed himself, he did, upon the promises made him by his dipping-rod, put himself to the great charge of digging in untry'd places for mines. Among the miners themselves, I found some who made use of this wand, and others that laugh'd at it. This I must take notice of, as peculiar to the experiment, that the most knowing patrons of it confess, that, in some mens hands it will not succeed: some hidden property in him who uses the wand, being able, as they say, to overpower and hinder its inclinatory virtue. To which I must add, what a very famous chymist, who affirms himself to have try'd many other things with it, besides those that are commonly known, very solemnly profess'd to me, upon his own knowledge, that, in the hands of those very persons wherein the rod will work, there are certain unlucky hours, govern'd by particular planets and constellations, during which, it will have no effect. But of this experiment I must say, as I do in all doubtful cases, that those who have seen it, may much more reasonably believe it, than those who have not.

Observations contingent, as well as experiments.

'Tis not only in experiments, but observations also, that much may be ascribed to contingency; witness the great variety in the number, magnitude, position, figure, *&c.* of the parts of a human body, taken notice of by anatomical writers; about which many errors would have been deliver'd, if the frequency of dissections had not enabled men to discern betwixt those things that are generally and uniformly found in anatomiz'd bodies, and those which are but rarely met with. I was lately present at a dissection, where we observ'd, that the interval betwixt two ribs, was, near the backbone, fill'd up with a thick bony substance, which seem'd to be an expansion of the ribs, and appear'd not to have grown there upon occasion of any fracture, or other mischance. Near the same time, being at a private dissection of a large young body, an ingenious professor of anatomy, there present, chancing to cut a great nerve, spy'd in the substance of it a little of a very red liquor; but, concluding it to be blood, I presently suspected, that it might proceed from some small unheeded drop, taken off, by the brushy substance of the nerve, from the knife wherewith it was cut. Wherefore, carefully wiping a dissecting knife, I cut the nerve asunder in a different part, and found another very little drop of pure blood in the substance of it, as before. This I did again, elsewhere, with like success; and shew'd it to the by-standers, who were surpriz'd to see a blood-vessel in the body of a nerve. This I the less admir'd, because I have, in the retina of an oxe's eye or two, observ'd little turgent veins, manifestly full of blood.

We farther observ'd, in the same body where we took notice of the irregular conjunction of two ribs, that the lungs, which were very sound, had a supernumerary lobe on one side, which differ'd so little from the others, that we did not, 'till we had display'd the whole, take notice of it. And I remember, in another dissection, the lungs, which otherwise appear'd.

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pear'd ſound, ſeeming, in ſeveral places, to be faſten'd to the ribs; two ingenious anatomiſts preſent, affirm'd, the one, that he had never ſeen any lungs, unleſs exceſſively morbid, adhering to the thorax; and the other, that he had ſcarce ever open'd a diſeaſed body, wherein the lungs did not thus adhere.

Many eminent authors declare, they have ſeldom fail'd to find the token of virginity among ſeveral females of their diſſecting; whilſt many other very eminent and experienced artiſts peremptorily profeſs, they have ſeldom or never found it in perſons of the moſt undoubted chaſtity: and certainly it is very ſtrange, that, about a matter which ſeems ſo eaſily determinable by ſenſe, accurate and ſober men ſhould ſo widely diſagree.

Tho' Dr. *Harvey*, and Dr. *Highmore*, both inſiſt on the production and changes obſervable in hens eggs, as the patterns whereto the generation of other animals may be referr'd: yet, in the progreſs of nature in the formation of a chick, we have often obſerv'd conſiderable variations, in point of time, and other circumſtances, from what they deliver. And this diverſity may eaſily proceed from the different conſtitutions of hens, their differing aſſiduity in ſitting on their eggs, the different qualifications of the eggs themſelves, and ſeveral other particulars of the like nature. And taking notice of this to Dr. *Highmore*, he readily acknowledg'd, that he himſelf had, likewiſe, obſerv'd ſeveral circumſtances in eggs, whilſt they were hatching, which varied from thoſe ſet down in his book; tho' he had there accurately expreſs'd the changes he diſcern'd in thoſe eggs, which, at that time, afforded him his obſervations. And, indeed, there are certain things of ſuch a nature, that the accuracy of ſcarce any ſingle man, in making an obſervation about them, can ſecure him from appearing unſkilful, or unfaithful in it, unleſs thoſe who ſhall afterwards examine the thing, ſhew more than ordinary equity and ſagacity.

He who firſt affirm'd, that a needle invigorated by a load-ſtone, conſtantly turn'd its extremes to the oppoſite poles of the earth, could ſcarce ſuſpect himſelf of having deliver'd any thing which he had not carefully try'd: yet which of thoſe two excellent pilots, *Oviedo* and *Cabot*, firſt in *America* compar'd the meridian line, afforded by magnetical needles, with one mathematically drawn, and thereby obſerv'd the variation of the needle, or its declination from the true meridian, might eaſily conclude our former obſerver miſtaken. And this ſecond obſervation might appear to have been as careleſly made to an hundred other obſervers, if navigation had not made it appear, that the declination of the needle is far from being the ſame in all places: for tho' *Cardan* affirms the load-ſtone to decline as many degrees, as the pole-ſtar is diſtant from the pole of the world; yet common experience ſufficiently manifeſts the falſity of that aſſertion. For about the iſlands of the *Azores*, eſpecially that of *Corvo*, over which the firſt meridian is ſuppoſed to paſs, the magnetic needle hath been obſerv'd to reſpect the poles, without any ſenſible declination from them; but, in other places, it varies ſometimes eaſtward, ſometimes weſtward, more or leſs; ſo that our venturous countryman, Captain *James*, obſerv'd it, in 63 degrees, north lati-

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latitude, to be no leſs than 27° 48′. And a late learned mathematical writer makes the declination, at *Davis*'s ſtreights, to amount to what is almoſt incredible, 50°. Nay, this deflection of the needle, ſometimes to one ſide of the meridian, ſometimes to the other, happens with ſo much irregularity, that both *Kircher*, and other magnetical writers, almoſt deſpair of reducing the obſervations of this kind to any general hypotheſis. And a great ſailor aſſur'd me, that near the coaſt of *Greenland*, he found the variation of the compaſs to be 22°. and not very long after to be ſcarce any at all; which ſtrange alteration he knew not what to make of. And perhaps very few, even of the exacteſt of theſe obſervations, made an age ſince, would now appear accurate to thoſe who ſhould examine them in the very ſame places, and the very ſame manner, wherein they were formerly made. So that the moſt diligent of thoſe obſervers would appear negligent to us, if the ſagacity of ſome of their ſucceſſors had not prompted them to ſuſpect, that even upon the ſame ſpot, the needle's variation may vary. And having, not long ſince, inquired of an excellent *Engliſh* mathematician, what he had obſerved concerning this alteration of the needle's variation; he told me, that by comparing of ancient obſervations with thoſe made by himſelf, and other accurate mathematicians at *London*, he had found the declination conſtantly to decreaſe; and, as he conjectured, 12 or 13 minutes in a year *. And it will be yet more difficult to ſet down any obſervation of this nature, which ſhall appear exact to poſterity, if that ſtrange thing be true, which was related to *Kircher*, by a friend of his, who affirms himſelf to have obſerv'd a notable change of the needle's variation, at *Naples*, after a great fiery eruption of the neighbouring mountain *Veſuvius*; which alteration he rationally ſuſpects to have proceeded from the very great change made in the adjacent ſubterraneal parts, by that great conflagration. And, it ſeems, the ſame obſervation has been elſewhere made by mathematicians. For *Fournier* tells us, that, ſince the great burnings of *Veſuvius*, the declination has notably chang'd in the kingdom of *Naples*. And the ſame author ſays, there are perſons, who have obſerv'd, that the ſame needle, which declin'd 5°. upon the ſurface of the earth, being carry'd down very low, into certain caves, declined quite otherwiſe; tho', poſſibly, thoſe who made the obſervation, might be miſtaken, without ſuſpecting it themſelves. For I ſhould ſcarce have imagined, unleſs my own particular obſervation had inform'd me, in how great a variety of ſtones and other foſſils, the ore of iron may lurk diſguiſed: ſo that 'tis no way incredible, that chymiſts themſelves, and, much more, that mathematicians, and others, not being aware of this particular, may preſume, becauſe they ſaw not any minerals, like the vulgar

* Dr. *Halley*, from conſidering the different variation of the needle, in different parts of the terraqueous globe, has advanced a very ingenious hypotheſis to ſolve the phenomena of it, by ſuppoſing that the whole earth is one great magnet, having four magnetic poles, or points of attraction, two near each pole of the equator; and that in the parts of the world near any one of theſe magnetic poles, the needle is govern'd thereby; the neareſt to the pole being always predominant over the more remote. *See* Philoſ. Tranſ. N°. 148. p. 208.

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iron ore, in the deep caves above-mention'd, that there is nothing of that metal there; when, indeed, there may be enough to occaſion that deflexion of the needle, which, eſpecially if it be ſtrongly excited, may be often drawn aſide by iron, or other magnetic bodies, at a greater diſtance, than thoſe, who have not try'd, would ſuſpect. And this may, perhaps, be the reaſon, why, in the little iſland of *Ilva*, upon the coaſt of *Italy*, where they dig up iron, and plenty of load-ſtones, of which, I have ſeen in *Tuſcany* of a prodigious bigneſs; there is, in the neighbouring places, ſuch a ſtrange diſparity of the needle's variation, as curious men have recorded. But magnetical and anatomical obſervations, are not the only ones, which are ſubject to diſagree, without the negligence of thoſe who make them.

I forbear to inſiſt on medicinal experiments and obſervations, becauſe they are ſo numerous, and univerſally ſubject to ſuch uncertainties, that it would be tedious. It is, indeed, much more difficult, than men can imagine, to make an accurate experiment in phyſic; for often, the ſame diſeaſe proceeding, in ſeveral perſons, from quite different cauſes, will be increas'd in one, by the ſame remedy which has cured it in another. And not only the conſtitutions of patients may as much alter the effects of remedies, as the cauſes of diſeaſes; but even in the ſame patient, and in the ſame diſeaſe, the ſingle circumſtance of time, may have almoſt as great an operation upon the ſucceſs of a medicine, as either of the two former particulars. But, beſides the general uncertainty, to which moſt remedies are ſubject, there are ſome few that ſeem obnoxious to contingencies of a peculiar nature. Such is the ſympathetic powder; of which, not only many phyſicians, and other ſober perſons, have aſſured me, they had ſucceſsfully made trial; but I have thought myſelf an eye-witneſs of its operation: and yet not only many have found it fail their expectation; but trying ſome of our own preparing, upon myſelf, I found it ineffectual, and unable to ſtop ſo much as a bleeding at the noſe; yet upon application of it, a little before, we had ſeen ſuch a bleeding, tho' violent, ſuddenly ſtop'd, in a perſon, who was ſo far from contributing, by his imagination, to the effect of the powder, that he derided thoſe whom he ſaw apply it to ſome drops of his blood. That therefore, the ſympathetic powder, and the weapon-ſalve, are never of any efficacy at all, I dare not affirm; but that they conſtantly perform what is promis'd of them, I muſt leave others to believe. Pioney-root has been much commended, both by antient and modern phyſicians, as an amulet againſt the falling-ſickneſs: yet has it, by many, been found ineffectual. I have been apt to ſuſpect, that its inefficacy might poſſibly proceed from having been unſeaſonably gather'd; and, when I was laſt in the weſt of *Ireland*, acquainting the moſt eminent *Galeniſt* there with my conjecture, he confirm'd me in it, by aſſuring me, that he had often try'd that root, unſeaſonably gather'd, without ſucceſs: but having lately gather'd it under its proper conſtellation, as they ſpeak, which is, when the decreaſing moon paſſes under *Aries*; and ty'd it, being firſt ſlit, about the neck and arms of his patients; he had cured more than one, whom he named to me, of the epilepſy. Agreeably hereto, I find, that a famous phyſician of *Grenoble*, Monſieur

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Monſieur *des Grands Prez*, in the laſt of his obſervations, communicated to the famous *Riverius*, ſolemnly profeſſes, he had, ſeveral times, freed his patients from the falling ſickneſs, by the ſingle outward application of piony-roots, collected and apply'd, as above mention'd. But, tho' he thence infers the uſefulneſs of obſerving the ſtars in the practice of phyſic; yet, before much ſtreſs be laid on ſuch improbable notions, as are the moſt of thoſe of judiciary aſtrologers, the influence of conſtellations upon ſimples, ought, by rigorous and competent experiments, to be better made out, than it hitherto has been.

But to leave contingent medicinal obſervations; I have obſerv'd, even mathematical writers, to deliver ſuch obſervations, as do not regularly hold true. For tho' they claim it, as their privilege, and glory to affirm nothing, but what they prove by demonſtration; and tho' they are uſually more attentive and exact, than moſt other men, in making philoſophical obſervations; yet the certainty and accuracy of what they deliver, muſt be reſtrain'd to thoſe purely mathematical ſtudies, arithmetic and geometry; where quantity is abſtractedly conſider'd: for we are not to expect the ſame accuracy, when they deliver obſervations of ſuch things, wherein matter, and its properties, muſt be conſider'd. And, much leſs ſhou'd this be expected, when they deliver obſervations made by the help of material inſtruments, fram'd by the hands and tools of men. Many modern aſtronomers have written of the *Maculæ* and *Faculæ* of the ſun, ſo, as to perſuade their readers, that ſome of them are almoſt conſtantly to be ſeen; and I am willing to think, that it was their having ſo often met with ſuch phenomena in the ſun, that made them write as they did; yet, when I firſt apply'd myſelf to the contemplation of theſe late diſcoveries, tho' I wanted neither good teleſcopes, nor a dark room, to bring the image of the ſun into; it was not till after a great while, and a multitude of fruitleſs obſervations, made at ſeveral times, that I could detect any of theſe ſpots, which have, during many months, appear'd ſo much ſeldomer than, it ſeems, they did before, that I remember a moſt ingenious profeſſor of aſtronomy, excellently well furniſh'd with dioptrical glaſſes, about that time complain'd to me, that for a very long while he had been unable to ſee them. And as for the *Faculæ*, that are written of as ſuch ordinary phenomena, I muſt profeſs that a multitude of obſervations, made with good teleſcopes, at ſeveral places and times, whilſt the ſun was ſpotted, has ſcarce given me to ſee, above once, the expected brightneſſes.

And, as the nature of the material object, regarded by the mathematician, may thus deceive the expectations, grounded on what he delivers; ſo, the like may happen, from the imperfection of the inſtruments employ'd in the ſenſible obſervations, whereon the mix'd mathematics depend. This is manifeſt in the diſagreeing computations, that famous writers have given us of the circumference of the terreſtrial globe; of the diſtance, and magnitude, of the fixed ſtars, and ſome of the planets; nay, and of the height of mountains: which diſagreement, as it may often proceed from the diſferent method, and unequal ſkill of the ſeveral obſervers; ſo in many

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caſes, it may be impuſted, to the greater or leſs exactneſs, and manageableneſs of the inſtruments employ'd. The great *Tycho Brahe*, who, beſides his time and induſtry, has beſtow'd vaſt ſums on aſtronomical inſtruments, deſerves to be heard on this occaſion. "A ſmall error," ſays he, "may be eaſily "committed, even with the larger inſtruments; and if the ſituation and "manner of uſing them be not wonderfully exact, abominable miſtakes will "be made. Beſides all this, the inſtruments themſelves, will, by uſe and "time, degenerate: for, unleſs they be exquiſitely made of ſolid metal, they "will ſuffer changes from the air; and, unleſs they are large, the diviſions "thereon cannot be ſufficiently exact. But in this caſe too, their weight and "bulk are detrimental; ſo that hence they eaſily decline from the proper "plane, or poſition, and grow unmanageable. And therefore, greater pre-"fection is required in aſtronomical inſtruments, and greater ſkill to manage "them, than has been hitherto generally taken notice of. This we have "found by long practice and experience, and with no ſmall coſt and labour."

And as for the obſervations made at ſea, *Fournier* adverti ſes us, that upon tryal of many inſtruments, both at ſea and a-ſhore, no aſtronomer in the world, can be ſure to make his obſervation at ſea, within ten minutes of the preciſe truth. And, indeed, the obſervations of ſkilful mathematicians may diſagree ſo much, when they pretend to give us the determinate meaſures of things, that, of three very eminent moderns, who have taken upon them to determine, from experiments, the proportion betwixt air and water, the one makes not the weight of the latter to exceed that of the former above 150 times; whilſt the other reckons water to be between 13 or 14 hundred times, and the third, no leſs than 10000 times, the heavier: not to mention a late famous writer or two, who have thought water, in compariſon of the air, vaſtly under-reckon'd, even by this laſt eſtimate. And, we have made an experiment, relating to this ſubject, which, tho' repeated ſeveral times in an hour, yet we fail'd twice as often as we ſucceeded in that time, without being able to know how the thing would prove before-hand, within ſome pounds weight.

Hence, then it appears, that thoſe experiments ſhould be ſeveral times very carefully try'd, upon which we mean to raiſe conſiderable ſuperſtructures, either theoretical or practical; and that it is unſafe to rely on ſingle experiments, eſpecially when minerals are concern'd: for many, to their coſt, have found, that what they at firſt look'd upon as a happy mineral experiment, has prov'd, in the iſſue, the moſt unfortunate.

And this diſcourſe may, alſo, ſerve as a kind of apology for ſober experimental writers, in caſe, we ſhould not always, upon tryal, find the experiments and obſervations they deliver, anſwer our expectations. And, indeed, it would prove a great diſcouragement to wary and conſiderate naturaliſts, from enriching the world with their obſervations, if they ſhould find, that their faithfulneſs, in ſetting down what they obſerv'd, is not able to protect them from the imputation of falſhood; but that by publiſhing any thing for the good of others, they muſt expoſe their reputation to all the uncertainties whereto their experiments may prove obnoxious. 'Tis true,

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true, indeed, if a writer be fabulous, or a plagiary, and delivers things, confidently, from hearſay; and his experiments, upon trial, ſucceed not; we may be allow'd to aſcribe their unſucceſsfulneſs rather to him, than to ourſelves, or chance. But if an author, uſually known to deliver things upon his own knowledge, and who ſhews himſelf careful not to be deceiv'd, and unwilling to deceive his readers, ſhall deliver any thing, as having try'd, or ſeen it, which, yet, agrees not with our experiments; 'tis a piece of equity to think, unleſs we have ſome manifeſt reaſon to the contrary, that he ſet down his experiment, or obſervation, as he made it; tho', for ſome latent reaſon, it does not conſtantly hold true.

Finding the Lord *Verulam* to deliver, that ſpirit of wine will ſwim upon oil of almonds, we immediately made trial of it; but, ſeveral times, found the oil to ſwim upon the ſpirit. Our tenderneſs, however, for the reputation of ſo great and candid a philoſopher, made us think, that, poſſibly, he might have uſed ſpirit of wine more pure than ordinary; and, therefore, having provided ſome that was well rectified, the oil readily ſunk therein, and lay quietly at the bottom. Thus, alſo, the learned Dr. *Brown* declaring, that *Aqua fortis* will quickly coagulate common oil, we put ſome of thoſe liquors together, and let them ſtand, for a conſiderable ſpace of time, in an open veſſel, without finding any ſuch change in the oil: but, being unwilling, that ſo candid and faithful a naturaliſt ſhould ſuffer in his character, we, again, made the trial with freſh oil and *Aqua fortis*, in a long-neck'd vial, left open at the top; which we kept both in a cool place, and afterwards, in a digeſting furnace: yet, after ſome weeks, we found no other alteration in the oil, than that it had acquir'd a high and lovely tincture. But, at length, ſuſpecting our materials, we chang'd them; and, repeating the experiment, found, after ſome hours, the oil coagulated into the form of a whitiſh butter. And, perhaps, I may myſelf, on ſome occaſions, ſtand in need of the like equity I have been careful to ſhew towards others. A very ſkilful chymiſt, by keeping ſalt in a vehement fire, for ſeveral days and nights together, and freeing the extracted liquor ſo carefully, both from its phlegm and terreſtrial feces, prepar'd a ſpirit from it; wherewith, I muſt freely confeſs I diſſolv'd crude gold: tho' I could not find, that the ſolutions I made of that metal were red, but, rather, of a yellow, or golden colour, much like thoſe obtain'd by *Aqua regis*. But, neither this artiſt, nor I, have been able to make another ſpirit of ſalt, capable of diſſolving gold, notwithſtanding all the induſtry we have employ'd about it: which makes me refer this to contingent experiments; unleſs the proſperous event of our former trial may be aſcrib'd to the quality of the ſalt diſtill'd, which was brought from the iſland of *Mayo*; where the ſcorching ſun makes, out of the ſea-water, a ſalt, that is accounted much ſtronger, and more ſpirituous, than that of *France*, and other more temperate climates. I once, alſo, inſtantly changed the colour of common oil, from a pale yellow, to a deep red, with a few drops of a liquor, that was almoſt colourleſs. But this experiment we have, ſeveral times, in vain, attempted to make again. And, therefore,

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when I am ſatisfied of the abilities and circumſpection of a writer, in delivering a matter of fact, upon his own knowledge, I do not, preſently, reject his obſervation, as untrue, when it ſeems to be contradicted by a more undoubted obſervation, or to contradict a receiv'd and plauſible hypotheſis, or tradition: but, rather try if, by a proper diſtinction, or limitation, I can reconcile them; unleſs there appears ſome cauſe, that might lead him to miſtake: for there ſometimes happen irregularities, contrary to the uſual courſe of things; as is evident in monſters; ſometimes, the receiv'd hypotheſis will not hold ſo univerſally as men preſume; and ſometimes, too, the contradiction betwixt the obſervations may be only imaginary, and ſo they may both be true.

That ſpiders are harmleſs in *Ireland*, is a known thing in that country; yet I dare not deny what the learned *Scaliger*, ſomewhere, affirms, that in *Gaſcony*, their venom is ſo pernicious, that they, ſometimes, poiſon thoſe who tread upon them, thro' the very ſoles of their ſhoes. And, even here in *England*, ſome ſpiders are venomous, without biting.

It is generally taken for granted, that, under the ſame meridian, the magnetic needle keeps, every where, the ſame variation; whence many perſons, upon reading the relations of the *Hollanders*, how, under the meridian, that paſſes by the iſland of *Corvo*, where the needle points directly to the poles, and which is, therefore, uſually reckon'd the firſt meridian, they found, at about 46° of northern latitude, a declination of about 7 or 8°: and, again, at about 55° of latitude, a far greater number; and alſo, under the 20th parallel of ſouthern latitude, in the ſame meridian of the *Azores*, 10 or 11° of declination; many perſons, I ſay, if they ſhould meet with theſe particulars, might ſuppoſe the *Dutch* to have been very bad obſervers, becauſe ſuch obſervations agree not with the theory of the needle's declination: yet, if we compare them with others of the like nature, made by good navigators, and ſkilful men, along other meridians; we may find cauſe, rather to rectify the general opinion, than reject the *Dutch* obſervations, for their diſagreeing with it. The jeſuit, *Jules Alenis*, (whom *Fournier* extols for the moſt accurate obſerver of the variation,) ſailing to *China*, writes thus. "You muſt," ſays he, "take notice of one thing very conſiderable; "namely, that the farther you go from the equator, in the ſame meridian, "the greater you will find the magnetical variation."

To conclude, tho', in the weſtern parts, it has been obſerv'd, that, generally, the inſide of trees is harder than the outward part; yet, *Fournier*, who was very well vers'd in the ſubject, treating of the building of ſhips, gives it us, for a very important remark, that they have obſerv'd, at *Marſeilles*, and all along the *Levant* ſhores, the wood, next the bark, to be ſtronger, than the heart of the tree.

But theſe things ſhould not diſcourage us from the vigorous proſecution of our inquiries into nature; nothing we have ſaid, can be interpreted to intimate more, than a great caution, in obſerving and relying on experiments. The phyſician does not renounce his profeſſion, becauſe many of his patients are not cured by his medicines; nor the huſbandman forſake his

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his plough, though, ſometimes, an unſeaſonable ſtorm, or flood, deſtroys his harveſt; becauſe they both ſucceed oftner than they fail: ſo neither ſhould we, by the contingencies incident to experiments, be deterr'd from making them; becauſe many are ſcarce ever obnoxious to caſualties: and even among thoſe, whoſe event is not ſo certain, we may, probably, make an experiment, very often, without meeting with any unlucky accident: and ſure the proſperous ſucceſs of many experiments, will well reward the pains employ'd on a few ſucceſsleſs attempts. And here too, it not unfrequently happens, that, even when we obtain not what we ſeek, we find ſomething as valuable. Thus merchants quit not their profeſſion, becauſe they, now and then, loſe a veſſel; or, frequently, have their ſhips forc'd into different ports, from thoſe they are bound for. And as the *American* navigators, employ'd by the *European* merchants, have, ſometimes, by ſtorms, been forc'd from their intended courſe, and driven upon unknown coaſts, and made diſcoveries of new regions, much more advantageous to them, than the faireſt winds, or moſt ſettled weather; ſo, in philoſophical trials, thoſe unexpected accidents, that defeat our endeavours, ſometimes caſt us upon new diſcoveries, of much greater advantage than the deſir'd ſucceſs would have proved.

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THE

PREFACE.

UNIVERSAL mechanics, or physics in general; which, in their full latitude, include whatever is knowable of the universe, and its parts; as they cannot be learnt, or taught at once, have, of necessity, been resolv'd into several distinct branches. Many of these branches have had particular names assign'd them; as, geography, astronomy, optics, chymistry, medicine, &c. *But that part of natural knowledge, which falls directly under none of these grand heads, seems, in a more restrain'd sense, to be call'd philosophy, or physics. This, however, is a large part of universal philosophy; and appears capable of affording new branches of science, worthy of particular names; or of being join'd to some of the others; as the astronomy of comets has, of late, been added to that of the planets. And, even, the consideration of a single production of nature, or a very few properties of some bodies, may give rise to a new branch of knowledge. Thus, the load-stone has introduced magnetics; and the reflexibility, and refrangibility of the sun's rays, the doctrine of light and colours.*

As new properties, therefore, come to be discover'd in bodies, universal mechanics will be enlarged, and increase in the number of its parts; till at length it becomes complete.

Hence it is, that so considerable a part of Mr. Boyle's *works stands under the head of physics; for he discover'd abundance of new properties in bodies, which had been but little consider'd; at least, had not been mechanically consider'd, before his time.*

The doctrine of the schools had then perverted philosophy, and render'd it unserviceable to mankind. But Mr. Boyle *has abolish'd their chimerical substantial forms, and other useless and ill-gr. unded notions, by letting in more light upon them; and shewn us the true origin of qualities in bodies: and this he has done, by such well chosen experiments, that they may, at once, instruct, delight, and benefit the reader,*

Indeed, Mr. Boyle *appears to have been, in all respects, one of the most profitable authors, who ever treated philosophy. He is not content, barely, to gain his point, and firmly to establish the doctrine he advances; but is curious in the choice of the materials he imploys to do it; and seldom produces an experiment, (of which, yet, he gives us a surprizing number) to confirm, or illustrate his assertions; but what may, some way or other, be made gainful to particular persons, and advan-*

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tageous to mankind, in general. This, evidently appears, in ſeveral of the following eſſays; as particularly, when he treats of forms, of colours, and of cold. His principal view in all his writings, ſeems to have been, to render them uſeful and inſtructive. He advances no barren theories, or deep abſtract ſpeculations; but lays down fertile principles, and proves and illuſtrates them by matters of fact, evident phenomena of nature, and appoſite and fruitful experiments.

Theſe experiments, 'tis true, are often taken from the laboratory; and require a little knowledge in chymiſtry, in order, fully, to underſtand and improve them. And it were greatly to be wiſh'd, that this art had a larger ſpread; and were more generally known, at leaſt in its fundamental operations, and more obvious phenomena. The deſign of our author, in ſome of the following pieces, was to ſhew how advantageouſly chymiſtry, which, thro' ill management, had almoſt ruin'd philoſophy, might be applied to the purpoſes of it. A deſign which the great Sir I. Newton *has executed ſo far, as, by means of that art, to account for moſt of the operations of nature, in the ſmaller portions of matter; as, by a like ſagacity, he has, with univerſal applauſe, ſolved the phenomena of the larger.*

Thus much for the author; I muſt next ſay a word to the abridgment. I deſire it may not be too haſtily cenſur'd, if, in ſome of the following pieces, and particularly in the Origin of Forms, *there is not that cloſeneſs of ſtyle obſerv'd, which we, at other times, employ; and which ſeems requiſite in an abridgment. A greater latitude of expreſſion was here made choice of, and ſome degrees of repetition admitted, in order to initiate and ground the leſs knowing, in the principles of the true philoſophy, by making all things as plain and eaſy as poſſible. To have contracted the matter cloſe, and never to have varied the manner of expreſſion, would have render'd the doctrine leſs intelligible; and, conſequently, leſs generally uſeful.*

Under this head of phyſics, I have been obliged to admit a few pieces of Mr. Boyle, *which, tho' properly philoſophical, yet, treating of the great author of the univerſe, may, to ſome, appear of too religious a nature for the place aſſign'd them. But a very great philoſopher aſſures us, that to treat of God from the phenomena of nature, is a part of experimental philoſophy, and accordingly, at the cloſe of the fineſt ſyſtem of that philoſophy, which was ever ſubmitted to the human capacity, he has, from the phenomena of the world, diſcover'd more of its grand author, than we could, otherwiſe, have well hoped to know. And at the concluſion of another treatiſe of a beautiful branch of knowledge, he tells us, that,* "*if the whole ſyſtem of philoſophy ſhall, at length, be perfected, the bounds of* "*moral philoſophy will, alſo, be enlarged; for ſo far as we can know by natural* "*philoſophy, what is the firſt cauſe, what power he has over us, and what benefits* "*we receive from him; ſo far our duty towards him, as well as that towards one* "*another, will appear to us by the light of nature.*"

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THE EXCELLENCE and GROUNDS OF THE Mechanical Philoſophy.

BY embracing the corpuſcular, or mechanical philoſophy, I am far from ſuppoſing, with the *Epicureans*, that, atoms accidentally meeting in an infinite vacuum, were able, of themſelves, to produce a world, and all its phenomena: nor do I ſuppoſe, when God had put into the whole maſs of matter, an invariable quantity of motion, he needed do no more to make the univerſe; the material parts being able, by their own unguided motions, to throw themſelves into a regular ſyſtem. The philoſophy I plead for, reaches but to things purely corporeal; and diſtinguiſhing between the firſt origin of things, and the ſubſequent courſe of nature, teaches, that God, indeed, gave motion to matter; but that, in the beginning, he ſo guided the various motion of the parts of it, as to contrive them into the world he deſign'd they ſhould compoſe; and eſtabliſh'd thoſe rules of motion, and that order amongſt things corporeal, which we call the laws of nature. Thus, the univerſe being once fram'd by God, and the laws of motion ſettled, and all upheld by his perpetual concourſe, and general providence; the ſame philoſophy teaches, that the phenomena of the world, are phyſically produced by the mechanical properties of the parts of matter; and, that they operate upon one another according to mechanical laws. 'Tis of this kind of corpuſcular philoſophy, that I ſpeak. *The mechanical Philoſophy, what.*

And the firſt thing, that recommends it, is, the intelligibleneſs, or clearneſs, of its principles and explanations. Among the peripatetics, there are many intricate diſputes about matter, privation, ſubſtantial forms, their eductions, &c. And, the chymiſts are puzzled to give ſuch definitions, and accounts, of their hypoſtatical principles, as are conſiſtent with one another, and to ſome obvious phenomena: and much more dark and intricate, are their doctrines about the *Archeus*, aſtral Beings, and other odd notions; which, perhaps, have, in part, occaſion'd the darkneſs and ambiguity of their expreſſions, that could not be very clear, when their conceptions were obſcure. And if the principles of the *Ariſtotelians*, and chymiſts, are thus obſcure, it is not to be expected, that the explications, made by *The principles of the mechanic philoſophy, clear and intelligible.*

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PHYSICS. the help of ſuch principles, only, ſhould be intelligible. And, indeed, many of them are ſo general and ſlight, or otherwiſe ſo unſatisfactory, that granting their principles, 'tis very hard to underſtand, or admit their applications of them to particular phenomena. And, methinks, even in ſome of the more ingenious and ſubtile of the peripatetic diſcourſes, the authors, upon their ſuperficial and narrow theories, have acted more like painters, than philoſophers; and only ſhewn their ſkill, in making men fancy they ſee caſtles, cities, and other ſtructures, that appear ſolid, magnificent, and extenſive; when the whole piece is ſuperficial, artificially made up of colours, and comprized within a frame. But, as to the corpuſcular philoſophy, men do ſo eaſily underſtand one another's meaning, when they talk of local motion, reſt, magnitude, ſhape, order, ſituation, and contexture, of material ſubſtances; and theſe principles afford ſuch clear accounts of thoſe things, that are rightly deduced from them alone; that, even ſuch peripatetics, or chymiſts, as maintain other principles, acquieſce in the explications made by theſe, when they can be had; and ſeek no further: tho', perhaps, the effect be ſo admirable, as to make it paſs for that of a hidden form, or an occult quality. Thoſe very *Ariſtotelians*, who believe the celeſtial bodies to be moved by intelligences, have no recourſe to any peculiar agency of theirs, to account for eclipſes: and, we laugh at thoſe *Eaſt-Indians*, who, to this day, go out in multitudes, with ſome inſtruments, to relieve the diſtreſſed luminary; whoſe loſs of light, they fancy, proceeds from ſome fainting fit; out of which, it muſt be rouz'd For no intelligent man, whether chymiſt, or peripatetic, flies to his peculiar principles, after he is inform'd, that the moon is eclipſed, by the interpoſition of the earth, betwixt her, and it; and the ſun, by that of the moon, betwixt him and the earth. And, when we ſee the image of a man, caſt into the air, by a concave ſpherical ſpeculum; tho' moſt men are amazed at it, and ſome ſuſpect it to be no leſs than an effect of witchcraft; yet he, who is ſkill'd enough in catoptrics, will, without conſulting *Ariſtotle*, or *Paracelſus*, or flying to hypoſtatical principles, or ſubſtantial forms, be ſatisfy'd, that the phenomenon is produced by rays of light reflected, and made to converge, according to optical, and mathematical laws.

Few. 2. I next obſerve, that there cannot be fewer principles, than the two grand ones of our philoſophy, matter, and motion; for matter, alone, unleſs it be moved, is wholly unactive; and, whilſt all the parts of a body, continue in one ſtate, without motion, that body will not exerciſe any action, or ſuffer any alteration; tho' it may, perhaps, modify the action of other bodies, that move againſt it.

Primary. 3. Nor, can we conceive any principles more primary than matter and motion: for, either both of them were immediately created by God; or, if matter be eternal, motion muſt either be produced, by ſome immaterial ſupernatural agent; or, it muſt immediately flow, by way of emanation, from the nature of the matter it appertains to.

Simple. 4. There cannot be any phyſical principles more ſimple, than matter and motion; neither of them being reſoluble into any other thing.

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5. The next thing, which recommends the corpuſcular principles, is, their extenſiveneſs. The genuine, and neceſſary effect of the ſtrong motion of one part of matter, againſt another, is either to drive it on, in its entire bulk, or, to break and divide it into particles of a determinate motion, figure, ſize, poſture, reſt, order, or texture. The two firſt of theſe, for inſtance, are each of them capable of numerous varieties: for the figure of a portion of matter, may either be one of the five regular geometrical figures, ſome determinate ſpecies of ſolid figures, or irregular, as the grains of ſand, feathers, branches, files, *&c.* And, as the figure, ſo the motion of one of theſe particles, may be exceedingly diverſified, not only by the determination to a particular part of the world; but by ſeveral other things: as by the, almoſt, infinitely different degrees of celerity; by the manner of its progreſſion, with, or without rotation, *&c.* and more yet by the line wherein it moves; as circular, elliptical, parabolical, hyperbolical, ſpiral, *&c.* For, as later geometricians have ſhewn, that theſe curves may be compounded of ſeveral motions, that is, deſcrib'd by a body, whoſe motion is mix'd, and reſults from two or more ſimple motions: ſo, how many more curves may be made by new compoſitions, and re-compoſitions of motion, is not eaſy to determine. PHYSICS. *And extenſive.*

Now, ſince a ſingle particle of matter, by virtue of only two mechanical properties, that belong to it, may be diverſify'd ſo many ways; what a vaſt number of variations, may we ſuppoſe capable of being produced by the compoſitions, and re-compoſitions of myriads of ſingle inviſible corpuſcles, that may be contain'd, and concreted in one ſmall body; and each of them be endued with more than two or three of the fertile, univerſal principles above-mentioned? And the aggregate of thoſe corpuſcles, may be further diverſify'd by the texture reſulting from their convention, into a body; which, as ſo made up, has its own magnitude, ſhape, pores, and many capacities of acting and ſuffering, upon account of the place it holds among other bodies, in a world, conſtituted like ours: ſo that, conſidering the numerous diverſifications, that compoſitions and re-compoſitions may make of a ſmall number; thoſe, who think the mechanical principles may ſerve, indeed, to account for the phenomena of ſome particular part of natural philoſophy, as ſtatics, the theory of the planetary motions, *&c.* but prove unapplicable to all the phenomena of things corporeal; ſeem to imagine, that by putting together the letters of the alphabet, one may, indeed, make up all the words to be found in *Euclid* or *Virgil*, or in the latin or engliſh language, but that they can by no means ſupply words to all the books of a great library; much leſs to all the languages in the world.

There are other philoſophers, who, obſerving the great efficacy of magnitude, ſituation, motion, and connexion, in engines, are willing to allow thoſe mechanical principles, a great ſhare in the operations of bodies of a ſenſible bulk, and manifeſt mechaniſm; and, therefore, to be uſefully employ'd, in accounting for the effects, and phenomena of ſuch bodies: tho' they will not admit, that theſe principles can be apply'd to the hidden tranſactions among the minute particles of bodies; and, therefore, think

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PHYSICS. think it neceſſary to refer theſe to what they call nature, ſubſtantial forms, real qualities, and the like immechanical agents. But this is not neceſſary: for, the mechanical properties of matter, are to be found; and the laws of motion take place, not only in the great maſſes, and the middle-ſiz'd lumps, but in the ſmalleſt fragments of matter: a leſs portion of it being as much a body, as a greater; muſt as neceſſarily, as the other, have its determinate bulk and figure. And, whoever views ſand thro' a good microſcope, will eaſily perceive, that each minute grain, has as well its own ſize and ſhape, as a rock or a mountain. Thus too, when we let fall a large ſtone, and a pebble, from the top of a high building; they both move conformably to the laws of acceleration, in heavy deſcending bodies: and the rules of motion are obſerv'd, not only in cannon-bullets, but in ſmall ſhot; and the one ſtrikes down a bird, according to the ſame laws, as the other batters a wall. And tho' nature works with much finer materials, and employs more curious contrivances, than art; yet an artiſt, according to the quantity of the matter he employs, the exigency of the deſign he undertakes, and the magnitude and ſhape of the inſtruments he uſes, is able to make pieces of work, of the ſame nature or kind, of extremely different bulks; where yet, the like art, contrivance, and motion, may be obſerved. Thus a ſmith, who, with a hammer, and other large inſtruments, can, out of maſſes of iron, forge great bars or wedges, to make ſtrong and ponderous chains to ſecure ſtreets and gates; may, with leſſer inſtruments, make ſmaller nails, and filings, almoſt as minute as duſt; and with yet finer tools, make links wonderfully light and ſlender. And, therefore, to ſay, that tho' in natural bodies, whoſe bulk is manifeſt, and their ſtructure viſible, the mechanical principles may be uſefully admitted; but are not to be extended to ſuch portions of matter, whoſe parts and texture are inviſible, is like allowing, that the laws of mechaniſm may take place in a town-clock, and not in a pocket-watch: or, becauſe the terraqueous globe is a vaſt magnetical body, one ſhould affirm, that magnetical laws are not to be expected manifeſt in a ſmall ſpherical piece of load-ſtone; yet, experience ſhews us, that, notwithſtanding the immenſe diſproportion betwixt theſe two ſpheres, the terella, as well as the earth, hath its poles, equator, and meridians; and, in ſeveral other magnetical properties, reſembles the terreſtrial globe.

When, to ſolve the phenomena of nature, agents are made uſe of, which, tho' they involve no contradiction in their notions, as many think ſubſtantial forms and real qualities do; yet are ſuch, that we conceive not how they operate to produce effects; ſuch agents I mean, as the ſoul of the world, the univerſal ſpirit, the plaſtic power, *&c.* the curioſity of an inquiſitive perſon is not ſatisfied hereby; who ſeeks not ſo much to know, what is the general agent that produces a phenomenon, as by what means, and after what manner, it is produced. *Sennertus*, and other phyſicians, tell us of diſeaſes, which proceed from incantation; but ſure, it is very trivial to a ſober phyſician, who comes to viſit a patient, reported to be bewitch'd, to hear only, that the ſtrange ſymptoms he meets with, and would

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would have an account of, are produced by a witch, or the devil; and he will never be ſatisfied with ſo ſhort an anſwer, if he can, by any means, reduce thoſe extravagant ſymptoms to any more known and ſtated diſeaſes; as epilepſies, convulſions, hyſteric fits, *&c.* and if he cannot, he will confeſs his knowledge of this diſtemper, to come far ſhort of what might be expected and attain'd in other diſeaſes, wherein he thinks himſelf bound to ſearch into the morbific matter; and will not be ſatisfied, till he can, probably, deduce from that, and the ſtructure of the human body, and other concurring phyſical cauſes, the phenomena of the malady. And, it would be but little ſatisfaction to one, who deſires to underſtand the cauſes of the phenomena in a watch, and how it comes to point at, and ſtrike the hours; to be told, that a certain watch-maker ſo contriv'd it: or, to him who would know the true cauſes of an echo, to be anſwer'd, that it is a man, a vault, or a wood, that makes it. PHYSICS.

I come now to conſider that, which, I obſerve, moſt alienates other ſects from mechanical philoſophy; *viz.* a ſuppoſition, that it pretends to have principles, ſo univerſal and mathematical, that no other phyſical hypotheſis can be tolerated by it.

This, I look upon, as an eaſy, indeed, but an important miſtake: for, the mechanical principles are ſo univerſal, and applicable to ſo many purpoſes, that they are rather fitted to take in, than to exclude, any other hypotheſis found on nature. And ſuch hypotheſes, if prudently conſider'd, will be found, as far as they have truth on their ſide, to be either legitimately deducible from the mechanical principles, or fairly reconcileable to them. For ſuch hypotheſes will, probably, attempt to account for the phenomena of nature, either, by the help of a determinate number of material ingredients, ſuch as the *tria prima* of the chymiſts; or elſe by introducing ſome general agents, as the *Platonic* ſoul of the world, and the univerſal ſpirit, aſſerted by ſome chymiſts; or, by both theſe ways together.

Now, the chief thing that a philoſopher ſhould look after, in explaining difficult phenomena, is not ſo much what the agent is, or does; as, what changes are made in the patient, to bring it to exhibit the phenomena propos'd; and by what means, and after what manner, thoſe changes are effected. So that the mechanical philoſopher being ſatisfied, one part of matter can act upon another, only by virtue of local motion, or, the effects and conſequences thereof; he conſiders, if the propoſed agent be not intelligible and phyſical, it can never phyſically explain the phenomena; and if it be intelligible and phyſical, it will be reducible to the matter, and, ſome, or other, of its univerſal properties. And the indefinite diviſibility of matter, the wonderful efficacy of motion, and the, almoſt, infinite variety of coalitions and ſtructures, that may be made of minute and inſenſible corpuſcles, being duly weigh'd; why may not a philoſopher think it poſſible, to make out, by their help, the mechanical poſſibility of any corporeal agent, how ſubtile, diffuſed, or active ſoever, that can be ſolidly proved to have a real exiſtence in nature? Tho' the *Carteſians* are mechanical philoſophers, yet their *Materia ſubtilis*, which the very name declares

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PHYSICS. to be a corporeal ſubſtance, is, for ought I know, little leſs diffus'd thro' the univerſe, or leſs active in it, than the univerſal ſpirit of ſome chymiſts; not to ſay the *Anima mundi* of the *Platoniſts*. But whatever be the phyſical agent, whether it be inanimate, or living, purely corporeal, or united to an intellectual ſubſtance; the above-mention'd changes, wrought in the body, made to exhibit the phenomena, may be effected by the ſame, or the like means; or after the ſame, or the like manner: as for inſtance, if corn be reduced to meal; the materials, and ſhape of the mill-ſtones, and their peculiar motion and adaptation, will be much of the ſame kind; and, to be ſure, the grains of corn will ſuffer a various attrition, and comminution in their paſſage to the form of meal, whether the corn be ground by a water-mill, or wind-mill, a horſe-mill, or a hand-mill; that is, a mill, whoſe ſtones are turn'd by inanimate, by brute, or by rational agents. And if an angel himſelf, ſhould work a real change in the nature of a body, 'tis ſcarce conceivable to men, how he could do it, without the aſſiſtance of local motion; ſince, if nothing were diſplac'd, or, otherwiſe mov'd than before, 'tis hardly conceivable, how it ſhould be, in itſelf, different from what it was before.

But if the chymiſts, or others, who would deduce a compleat natural philoſophy, from ſalt, ſulphur, and mercury, or any determin'd number of ingredients of things, would well conſider what they undertake, they might eaſily diſcover, that the material parts of bodies can reach but to a few phenomena of nature, whilſt theſe ingredients are conſider'd but as quieſcent things, whence, they would find themſelves oblig'd to ſuppoſe them active; and that things, purely corporeal, cannot, but by means of local motion, and the effects that may reſult from it, by variouſly ſhap'd, fiz'd, and combined parts of matter: ſo that the chymiſts muſt leave the greateſt part of the phenomena of the univerſe unexplain'd, by means of the ingredients of bodies, without taking in the mechanical and more comprehenſive properties of matter, eſpecially local motion. I willingly grant, that ſalt, ſulphur, and mercury, or ſome ſubſtances analogous to them, are obtainable, by the action of the fire, from a very great many diſſipable bodies here below. Nor do I deny, that, in explaining ſeveral phenomena of ſuch bodies, it may be of uſe to a naturaliſt, to know, and conſider, that, as ſulphur, for inſtance, abounds in the body propos'd, it may be, thence, probably argued, that the qualities, uſually attending that principle, when predominant, may be, alſo, upon its account, found in the body that ſo largely partakes of it. But, tho' chymical explications are, ſometimes, the moſt obvious, yet they are not the moſt fundamental, and ſatisfactory: for the chymical ingredient itſelf, whether ſulphur, or any other, muſt owe its nature, and other qualities, to the union of inſenſible particles, in a convenient ſize, ſhape, motion, or reſt, and texture; all which are but mechanical properties of convening corpuſcles. And this may be illuſtrated by what happens in artificial fire-works. For, tho' in moſt of thoſe ſorts, made either for war, or recreation, gun-powder be a principal ingredient; and many of the phenomena may be deriv'd from the greater

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greater or leſs proportion, wherein it enters the compoſitions: yet there may be fire-works made without gun-powder, as appears by thoſe of the ancient *Greeks*, and *Romans*. And gun-powder owes its aptneſs to fire, and to be exploded, to the mechanical texture of more ſimple portions of matter, nitre, charcoal, and ſulphur. And ſulphur itſelf, tho' it be by many chymiſts miſtaken for an hypoſtatical principle, owes its inflammability to the union of ſtill more ſimple and primary corpuſcles; ſince chymiſts confeſs, that it has an inflammable ingredient: and experience ſhews, that it very much abounds with an acid and uninflammable ſalt, and is not deſtitute of a terreſtrial part. It may, indeed, be here alledg'd, that the productions of chymical analyſes, are ſimple bodies; and, upon that account, irreſoluble. But, that ſeveral ſubſtances, which chymiſts call the ſalts, ſulphurs, or mercuries of the bodies that afford them, are not ſimple and homogeneous, is demonſtrable. Nor is their not being eaſily diſſipable, or reſoluble, a clear proof of their not being made up of more primitive portions of matter. For compounded bodies may be as difficultly reſoluble, as moſt of thoſe that chymiſts obtain by the fire: witneſs common green-glaſs, which is far more durable, and irreſoluble, than many of thoſe which paſs for hypoſtatical ſubſtances. And ſome amels will, for ſeveral times, even vitrify in the forge, without loſing their nature, or, often, ſo much as their colour: yet, amel conſiſts of ſalt, powder of pebbles, or ſand, and calcined tin; and, if not white, uſually of ſome tinging metal, or mineral. But how indeſtructible ſoever the chymical principles are ſuppoſed, ſeveral of the operations aſcribed to them, will never be made appear, without the help of local motion: were it not for this, we can but little better ſolve the phenomena of many bodies, by knowing what ingredients compoſe them, than we can explain the operations of a watch, by knowing of how many, and of what metals, the balance, the wheels, the chain, and other parts conſiſt; or than we can derive the operations of a wind-mill, from barely knowing, that 'tis made up of wood, ſtone, canvaſs, and iron. And here let me add, that it would not, at all, overthrow the corpuſcularian hypotheſis, tho', either by more exquiſite purifications, or by ſome other operations, than the uſual analyſis by fire, it ſhould appear, that the material principles of mix'd bodies, are not the *tria prima* of the vulgar chymiſts; but, either ſubſtances of another nature, or fewer in number; or, if it were true, that the *Helmontians* had ſuch a reſolving menſtruum, as their maſter's alkaheſt, by which, he affirms, that he could reduce ſtones into ſalt, of the ſame weight with the mineral; and bring both that ſalt, and all other mix'd and tangible bodies, into inſipid water. For, whatever be the number or qualities of the chymical principles, if they really exiſt in nature, it may, very poſſibly, be ſhewn, that they are made up of inſenſible corpuſcles, of determinate bulks and ſhapes: and, by the various coalitions, and textures of ſuch corpuſcles, many material ingredients may be compoſed, or made to reſult. But tho' the alkaheſtical reductions, newly mention'd, ſhould be admitted, yet the mechanical prin-

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PHYSICS. ciples might well be accommodated even to them. For the ſolidity, taſte, &c. of ſalt, may be fairly accounted for, by the ſtiffneſs, ſharpneſs, and other mechanical properties of the minute particles, whereof ſalt conſiſts: and if, by a farther action of the alkaheſt, the ſalt, or any other ſolid body, be reduced into inſipid water, this, alſo, may be explain'd by the ſame principles; ſuppoſing a farther comminution of its parts, and ſuch an attrition, as wears off the edges and points that enabled them to ſtrike briſkly upon the organ of taſte: for as to fluidity and firmneſs, they, principally, depend upon two of our grand principles, motion, and reſt. And, 'tis certain, that the agitation, or reſt, and the looſer contact, or cloſer coheſion of the particles, is able to make the ſame portion of matter, at one time, a firm, and, at another, a fluid body. So that, tho' future ſagacity, and induſtry of chymiſts, ſhould obtain, from mix'd bodies, homogeneous ſubſtances, different in number, nature, or both, from their vulgar ſalt, ſulphur, and mercury; yet the corpuſcular philoſophy is ſo general and fertile, as to be fairly reconcilable to ſuch a diſcovery; and, alſo, ſo uſeful, that theſe new material principles will, as well as the old *tria prima*, ſtand in need of the more univerſal principles of the corpuſcularians; eſpecially of local motion. And, indeed, whatever elements, or ingredients, men have pitch'd upon; yet, if they take not in the mechanical properties of matter, their principles are ſo deficient, that I have obſerv'd, both the materialiſts and chymiſts, not only leave many things unexplain'd, to which their narrow principles will not extend; but, even in the particulars they preſume to give an account of, they either content themſelves to aſſign ſuch common and indefinite cauſes, as are too general to be ſatisfactory; or, if they venture to give particular cauſes, they aſſign precarious or falſe ones, liable to be eaſily diſproved by circumſtances, or inſtances, whereto their doctrine will not agree. The chymiſts, however, need not be frighted from acknowledging the prerogative of the mechanical philoſophy, ſince that may be reconcilable with the truth of their own principles, ſo far as they agree with the phenomena they are applied to: for theſe more confined hypotheſes may be ſubordinate to thoſe more general and fertile principles; and there can be no ingredient aſſign'd that has a real exiſtence in nature, but may be deriv'd, either immediately, or by a row of compoſitions, from the univerſal matter, modified by its mechanical properties. For if with the ſame bricks, differently put together, and rang'd, ſeveral bridges, vaults, houſes, and other ſtructures may be raiſed merely by a various contrivance of parts of the ſame kind; what a great variety of ingredients may be produced by nature, from the various coalitions and contextures of corpuſcles, that need not be ſuppos'd, like bricks, all of the ſame ſize and ſhape; but to have, both in the one and the other, as great a variety as could be wiſh'd for? And the primary and minute concretions, that belong to theſe ingredients, may, without oppoſition from the mechanical philoſophy, be ſuppos'd to have their particles ſo minute, and ſtrongly coherent, that nature, of herſelf, ſcarce ever tears them aſunder. Thus mercury and gold may be

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be ſucceſſively made to put on a multitude of diſguizes; and yet ſo retain their nature, as to be reducible to their priſtine forms. PHYSICS.

From hence, it is probable, if, beſides rational ſouls, there be any immaterial ſubſtances, ſuch as the heavenly intelligences, and the ſubſtantial forms of the *Ariſtotelians*, that are regularly to be number'd among natural agents; their way of working being unknown to us, they can only help to conſtitute and effect things, but will very little help us to conceive how things are effected; ſo that, by whatever principles natural things are conſtituted, 'tis, by the mechanical principles, that their phenomena muſt be clearly explain'd. For inſtance, tho' we grant, with the *Ariſtotelians*, that the planets are made of a quinteſſential matter, and mov'd by angels, or immaterial intelligences; yet, to explain the ſtations, progreſſions, and retrogradations, and other phenomena of the planets, we muſt have recourſe either to excentrics, epicycles, *&c.* or to motions made in elliptical or other peculiar lines; and, in a word, to theories, wherein the motion, figure, ſituation, and other mathematical, or mechanical properties are chiefly employ'd. But, if the principles propos'd be corporeal, they will then be fairly reducible, or reconcilable to the mechanical principles; theſe being ſo general and fertile, that, among real material things, there is none but may be deriv'd from, or reduced to them. And when the chymiſts ſhall ſhew that mix'd bodies owe their qualities to the predominancy of any one of their three grand ingredients, the corpuſcularians will ſhew, that the very qualities of this, or that ingredient, flow from its peculiar texture, and the mechanical properties of the corpuſcles that compoſe it. And to affirm, that becauſe the chymical furnaces afford a great number of uncommon productions, and phenomena, that there are bodies, or operations, amongſt things purely corporeal, not derivable from, or reconcilable to the principles of mechanical philoſophy; is to ſay, becauſe there are many and varions hymns, pavins, threnodies, courants, gavots, ſarabands, *&c.* in a muſic book, many of the tunes, or notes, have no dependance on the ſcale of muſic; or as if, becauſe excepting rhomboids, ſquares, pentagons, chiliagons, and numerous other polygons, one ſhould affirm there are ſome rectilineal figures, not reducible to triangles, or that have properties which overthrow *Euclid*'s doctrine of triangles, and polygons.

I ſhall only add, that as mechanical principles, and explanations, where they can be had, are, for their clearneſs, preferr'd by materialiſts themſelves; ſo the ſagacity and induſtry of modern naturaliſts, and mathematicians, having happily apply'd them to ſeveral of thoſe difficult phenomena, which before were referr'd to occult qualities, 'tis probable, that when this philoſophy is more ſcrutiniz'd, and farther improv'd, it will be found applicable to the ſolution of ſtill more phenomena of nature. And 'tis not always neceſſary, that he who advances an hypotheſis in aſtronomy, chymiſtry, anatomy, *&c.* be able, *à priori*, to prove it true, or demonſtratively to ſhew that the other hypotheſis, propos'd about the ſame ſubject, muſt be falſe; for, as *Plato* ſaid, that the world is God's epiſtle to mankind; and

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PHYSICS. might have added, in his own way, that it was written in mathematical characters; ſo, in the phyſical explanations of the parts and ſyſtem of the world, methinks, there is ſomewhat like what happens, when men conjecturally frame ſeveral keys to read a letter written in cyphers. For tho' one man, by his ſagacity, finds the right key, it will be very difficult for him, either to prove, otherwiſe than by trial, that any particular word is not ſuch as 'tis gueſs'd to be by others, according to their keys; or to ſhew, *à priori*, that theirs are to be rejected, and his to be prefer'd: yet, if due trial being made, the key he propoſes be found ſo agreeable to the characters of the letter, as to enable one to underſtand them, and make coherent ſenſe of them, its ſuitableneſs to what it ſhould decypher, is, without either confutations, or foreign poſitive proofs, alone ſufficient to make it accepted as the right key of that cypher. Thus, in phyſical hypotheſes, there are ſome, that, without falling foul upon others, peaceably obtain the approbation of diſcerning men, only by their fitneſs to ſolve the phenomena for which they were deviſed, without thwarting any known obſervation, or law of nature: and therefore, if the mechanical philoſophy ſhall continue to explain corporeal things, as it has of late, 'tis ſcarce to be doubted, but that, in time, unprejudiced Perſons will think it ſufficiently recommended, by its being conſiſtent with itſelf, and applicable to ſo many phenomena of nature.

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THE ORIGIN OF FORMS and QUALITIES;

Serving as an Introduction to the MECHANICAL PHILOSOPHY.

SECT. I.

THE doctrine I ſhall here attempt to eſtabliſh, take as follows.

1. There is one univerſal matter, common to all bodies, an extended, diviſible, and impenetrable ſubſtance. *An univerſal matter.*

2. This matter being in its own nature but one, the diverſity in bodies muſt neceſſarily ariſe from ſomewhat elſe; and ſince there could be no change in matter at reſt, there is a neceſſity of motion to diſcriminate it; and for that motion, alſo, to have various tendencies. *The neceſſity of motion.*

Motion, in many parts of matter, appears manifeſt to ſenſe; but how it came by this motion, is diſputed. The ancient corpuſcularians, who acknowledged no author of the univerſe, were reduced to make it inherent in matter; and, conſequently, coeval therewith: but ſince local motion, or an endeavour at it, is not included in the nature of matter, which is as much matter when at reſt, as when in motion; and, ſince the ſame portion of matter, may from motion be reduced to reſt; and, after it hath continued at reſt, as long as other bodies do not put it out of that ſtate, may, by external agents be moved again; I am of opinion, that the origin of motion in matter, is from God; as, alſo, the laws by which it operated in bringing the world to its preſent frame: ſo that local motion ſeems to be the principal amongſt ſecond cauſes, and the grand efficient of all that happens in nature. For tho' bulk, figure, reſt, ſituation, and texture, concur to the phenomena of nature; yet, in compariſon of motion, they ſeem, in many caſes, to be effects, and *Whence motion proceeds.*

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PHYSICS. in others, little better than conditions or requisites, which modify the operation, that one part of matter, by virtue of its motion, hath upon another; as in a watch, the number, the figure, and correspondence of the wheels and other parts, are requisite to the performing the office of a watch; but, 'till these parts are actually put in motion, all their other properties remain inefficacious. Thus, also, a key, tho' it were too big or too little, or its shape unfit for that of the cavity of the lock, would not perform its office, tho' put into motion; yet, let its size and figure be never so fit, unless actual motion intervene, it will never lock or unlock: as, without the like actual motion, a knife, or razor, will not actually cut, how much soever their shape, and other qualities, fit them for that action. So brimstone, what disposition of parts soever it has to be turned into flame, would never be kindled, unless some actual fire, or other vehemently and variously agitated matter, puts the sulphureous corpuscles into a very brisk motion *.

Matter divisible.

3. These two principles, matter and motion, being established, it will follow, that matter must be actually divided into parts; and that each of the primitive fragments, or other distinct and entire masses, must have two attributes, its own magnitude or size, and its own figure or shape. And, since experience shews, that this division of matter is frequently made into insensible particles: we may conclude, that the minutest fragments, as well as the largest portions of the universal matter, have, likewise, their peculiar bulk and shape. For being a finite body, its dimensions must be terminated, and measurable; and tho' it may change its figure, yet it will necessarily have some figure or other. We must, therefore, admit three essential properties of each entire part of matter, *viz.* magnitude, shape, and either motion or rest: the two first of which may be called inseparable accidents; because matter being extended, and yet finite, it is physically impossible, that it should be destitute of some bulk and determinate shape.

The notion of real qualities examin'd.

Whether these accidents may not be called the modes, or primary affections of bodies, to distinguish them from the less simple qualities, colours, tastes, &c. that belong to bodies upon their account; or whether, with the

* Motion is generally defin'd to be, the translation of a body from one place to another: but this translation, seems rather the effect of motion, than motion itself. Whatever is said to be in motion, may be consider'd, either with regard to the parts of immovable and infinite space; to the remote bodies that surround it; or to the surface of what is nearest to it. Now, as the parts of space are infinite and immovable, and have nothing in common with the alterations of matter; that change of situation, which respects the parts of space, without the least regard to the surrounding bodies, may properly be called absolute motion. Again, a body, said to be in motion, may be compared with bodies remote: and, as a body may here be transfer'd, together with such as are near it; that change of situation, which is made with regard to bodies at a distance, may be termed common relative motion. In the last place, a body supposed in motion, may be compar'd with the surface of those bodies, which are very near it: and as in this case, the body may have neither an absolute, nor a common motion; and, what is thus at rest, may, in reality, have them both; we may call this change of situation, proper relative motion. See *Clarke Annot. in Rohault. Physic.* Ed. 3. p. 36—38. and *Newton Princip.* Ed. 2. p. 6—11.

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Epicureans, they may not be called the conjuncts of the ſmalleſt parts of matter, I ſhall not now conſider. But the ſchools teach, that there are in natural bodies, many real qualities, and other real accidents, which not only are no modes of matter, but real entities diſtinct from it. Now, accident is, by logicians, uſed in two ſeveral ſenſes: ſometimes it is oppoſed to the fourth predicable, or property, and is then defined, "that which may be preſent or abſent, "without the deſtruction of the ſubject:" as a man may be ſick or well, and a wall white or black; and yet the one be ſtill a man, and the other a wall: and this, in the ſchools, is call'd *Accidens prædicabile*, to diſtinguiſh it from what they call *Accidens prædicamentale*, which is oppoſed to ſubſtance. And, as ſubſtance is commonly defined to be a thing, that ſubſiſts of itſelf, and the *ſubſtratum* of accidents; ſo an accident is ſaid to be *id cujus eſſe eſt ineſſe*: and therefore *Ariſtotle*, who uſually calls ſubſtances ſimply ὄντα, entities, moſt commonly calls accidents ὄντος ὄντα, entities of entities; theſe requiring the exiſtence of ſome ſubſtance wherein to reſide, as in their ſubject of inheſion. And, becauſe logicians make it the diſcriminating mark of ſubſtance from accident, that it cannot exiſt in another thing, as in its ſubject of inheſion, it is requiſite to know, that, according to them, a thing is in a ſubject, which, however it be in another thing, is not in it as a part, and cannot exiſt ſeparately from the thing wherein it is: as a white wall is the ſubject of inheſion of the whiteneſs we ſee in it; which ſame whiteneſs, tho' it be not in the wall as a part of it; yet cannot, according to our logicians, exiſt any where out of the wall, tho' many other bodies may have the like degree of whiteneſs. This premiſed, it will not be hard to diſcover the abſurdity of the opinion, juſt mention'd, of real qualities and accidents; the ſchool-doctrine about which, appears to be either unintelligible, or manifeſtly contradictory. For, ſpeaking in a phyſical ſenſe, if they will not allow theſe accidents to be modes of matter, but entities really diſtinct from it, and, in ſome caſes, ſeparable from all matter; they make them, indeed, accidents in name, but repreſent them under ſuch a notion, as belongs only to ſubſtances: the nature of a ſubſtance conſiſting in this, that it can ſubſiſt of itſelf, without being in any thing elſe, as in a ſubject of inheſion: ſo that to tell us, a quality, or other accident, may ſubſiſt without a ſubject, is to allow it the true nature of ſubſtance. Nor could I ever find it intelligibly made out, what theſe real qualities are, that they deny to be either matter, or modes of matter, or immaterial ſubſtances. When a bowl is in motion or at reſt, that motion or reſt, or globular figure of the bowl, is not nothing, yet no part of the bowl; whoſe whole ſubſtance would remain, tho' it wanted any one of theſe accidents: and to make them real and phyſical entities, is, as if, becauſe we may conſider the ſame man ſitting, ſtanding, running, thirſty, hungry, &c. we ſhould make each of theſe a diſtinct entity, as we give ſome of them diſtinct names: whereas, the ſubject of all theſe qualities is but the ſame man, conſidered with circumſtances which may make him appear different in one caſe, from what he appears in another. And, we muſt here obſerve, that not only diverſity of names, but even diverſity of definitions, does not always infer a diverſity of phyſical entities in the ſubject.

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PHYSICS. ject whereto they are attributed. For it happens in many of the phyſical attributes of a body, as it does where a man, who is a father, a huſband, a maſter, a prince, *&c.* may have a peculiar definition in each of theſe capacities; and yet the man, conſider'd in himſelf, is but the ſame man, who, in reſpect of different capacities or relations to other things, is called by different names, which conclude not ſo many real and diſtinct entities in the perſon thus variouſly denominated.

The relative nature of phyſical qualities.

But becauſe this notion may be of great importance to the nature of qualities; we may farther conſider, that when the ſmith, who firſt invented locks and keys, had made his firſt lock, it was only a piece of iron, contrived into a particular ſhape; and when, afterwards, he made a key to it, that alſo, conſider'd in itſelf, was nothing but a piece of iron of a determinate figure; but as theſe two pieces of iron might now be applied to one another, after a certain manner; and, as there was a congruity betwixt the wards of the lock and thoſe of the key, the lock and the key now, each of them, obtain'd a new capacity; and it became a principal part of the notion and deſcription of a lock, that it was capable of being made to lock or unlock, by that other piece of iron we call a key; and it was look'd upon as a peculiar faculty and power in the key, to be fit to open and ſhut the lock: and yet, by theſe new attributes there was not added any real or phyſical entity, either to the lock or the key; each of them remaining the ſame piece of iron, juſt ſo ſhaped as it was before. And when the ſmith made other keys of different ſizes, or with differing wards; tho' the firſt lock could not be opened with any of thoſe keys, yet, that indiſpoſition was nothing new in the lock, or diſtinct from the figure it had, before thoſe keys were made. To carry this compariſon a little further; tho' one, who had defined the firſt lock and the firſt key, would have done it by diſtinct definitions; yet, theſe definitions being given only upon account of certain reſpects, which the defined bodies had to one another, would not infer, that the two iron inſtruments phyſically differ'd, otherwiſe than in the figure, ſize, or contrivance of the iron, whereof each conſiſted. Thus, why may we not conceive, that as to thoſe qualities which we call ſenſible, for inſtance, tho' by virtue of a certain congruity, or incongruity, in point of figure or texture, or other mechanical properties, to our ſenſes, the portions of matter they modify are enabled to produce various effects, upon account whereof bodies are ſaid to be endowed with qualities; yet, that they are not, in the bodies endowed with them, any real, or diſtinct entities, or differing from the matter itſelf, of ſuch a determinate bigneſs, ſhape, or other mechanical modifications? And thus tho' the modern goldſmiths and refiners, reckon it amongſt the moſt diſtinguiſhing qualities of gold, that it is diſſoluble in *Aqua regia*, whilſt *Aqua fortis* will not work upon it; yet theſe attributes are not, in the gold, any thing diſtinct from its peculiar texture; nor is the gold we have now of any other nature, than it was in *Pliny*'s time, when *Aqua fortis* and *Aqua regia* were unknown. And if another menſtruum, of which poſſibly I am poſſeſs'd, ſhould be invented to diſſolve pure gold in part, and change it into a different metalline body, there

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there will then ariſe another new property, whereby to diſtinguiſh this from other metals: yet the nature of gold is not at all different now, from what it was before the diſcovery of this laſt menſtruum. There are bodies neither cathartic nor ſudorific, with ſome of which gold being joined, acquires a purgative virtue, and with others a power to procure ſweat. Nature herſelf, ſometimes produces things, that have new relations to others: and art, eſpecially if aſſiſted by chymiſtry, may cauſe ſo many new productions, that no man can tell, but the moſt familiar bodies may have multitudes of qualities, he dreams not of, which will hardly be imagined real phyſical entities. Beaten glaſs is commonly reckoned among poiſons; yet, its deſtructive faculty, ſuppoſed to be a peculiar entity in the beaten glaſs, is really nothing diſtinct from the glaſs itſelf, ſuppoſed of a determinate bigneſs and figure of parts, acquir'd by comminution. For theſe glaſſy fragments being numerous, rigid, ſmall, and endowed with ſharp points and cutting edges, are enabled, by theſe mechanical properties, to wound the tender membranes of the ſtomach and guts, and produce all the effects uſually aſcribed to ſome poiſons: yet, the ſame is found to do no harm, where it is ſo finely powder'd, as not to wound the inteſtines. Accordingly we ſee, that the fragments of ſapphires, cryſtals, and rubies, things much harder than glaſs, are innocently uſed in cordial compoſitions; being, by grinding, reduced to a powder too ſubtile to excoriate the ſtomach. Hence the multiplicity of qualities in the ſame natural bodies, may proceed from the bare texture, and other mechanical affections of their matter: for we muſt conſider each body, not barely, as it is in itſelf, an entire and diſtinct portion of matter, but as a part of the univerſe; and, conſequently, placed amongſt a great number and variety of other bodies, upon which it may act, and by which it may be acted upon ſeveral ways; each whereof, men are apt to fancy a diſtinct power or quality in the body, whereby thoſe actions, or in which thoſe paſſions, are produced. We all know, that the ſun hath a power to harden clay, ſoften wax, melt butter, thaw ice, turn water into vapour, make air expand itſelf in weather-glaſſes, contribute to blanch linen, render the white ſkin of the face ſwarthy, and mowed graſs yellow, to ripen fruit, hatch the eggs of ſilk-worms, caterpillars, *&c.* and perform many other things, ſome of which ſeem contrary to others; yet, theſe are not diſtinct powers or faculties in the ſun, but only the productions of its heat, diverſified by the different textures of the body it chances to work on, and the condition of the other ſubſtances concerned in the operation. And therefore, whether the ſun, in ſome caſes, has any influence at all diſtinct from its light and heat, we ſee that all the phenomena mention'd, are producible by the heat of common fire, duly applied and regulated. And, to give an inſtance of another kind; having cauſed ſome ſolid balls of iron, ſkilfully hardened, and exquiſitely ſhaped and glazed, to be purpoſely made, each of them proved a ſpherical looking-glaſs; which, placed in the midſt of a room, exhibited the images of the ſurrounding objects in a very regular and pleaſing manner; yet the globe endowed with all theſe properties, was but iron reduced by the artificer to a ſpherical figure: and numerous *ſpecula*, may be immediately

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PHYSICS. diately made, by breaking a large drop of quick-ſilver into ſeveral little ones, each of which will ſerve for objects placed near it; and the ſmaller whereof, may, with a good microſcope, afford a pleaſant proſpect of the neighbouring objects; tho' to reduce a parcel of ſtagnant quick-ſilver into many of theſe little ſpherical *ſpecula*, whoſe properties are ſo differing from thoſe of plain ones, there is nothing required, but a ſlight local motion, which, in the twinkling of an eye, changeth the figure of the ſelf-ſame matter.

Texture another requiſite.

4. And ſuppoſing all the univerſe annihilated, except any of the entire corpuſcles, above-mention'd, it is hard to ſay, what could be attributed to it, beſides matter, motion, reſt, bulk, and ſhape: but there being now actually in the univerſe, great multitudes of corpuſcles intermixed with one another, there ariſe in every diſtinct portion of matter, which a number of them make up, two new accidents; the one whereof more relates to each particular corpuſcle, in regard to the ſtable bodies about it, namely, its poſture: but when two or more ſuch bodies are placed by one another, the manner of their being ſo placed, may be called their order. And when many corpuſcles convene together, ſo as to compoſe any diſtinct body, as a ſtone or a metal; then, from their other accidents, (or modes) and from theſe two laſt mentioned, there ariſes a certain diſpoſition, or contrivance of parts, in the whole, which we call the texture of it.

Senſible qualities only relative.

5. And if we ſhould conceive the univerſe to be annihilated, except one ſuch body, ſuppoſe a metal, or a ſtone, it were hard to ſhew, that there is, phyſically, any thing more in it than matter, and the accidents already mentioned. But now we are to conſider, that there actually are in the world, certain ſenſible and rational beings, called men; and the human body, having ſeveral of its external parts, as the eye, the ear, *&c.* each of a diſtinct and peculiar texture, whereby it is capable to receive impreſſions from the bodies about it, and, upon that account, called an organ of ſenſe; we muſt obſerve, that theſe ſenſes may be wrought upon by the figure, ſhape, motion, and texture of bodies without them, after ſeveral ways: ſome of thoſe external bodies being fitted to affect the eye, others the ear, others the noſtrils, *&c.* And to theſe operations of the objects on the ſenſes, the mind of man, which, upon account of its union with the body, perceives them, gives diſtinct names; calling the one light, or colour, the other ſound, the third odour, *&c.* And becauſe, alſo, each organ of ſenſe, as the eye, or the palat, may itſelf be differently affected by external objects, the mind, likewiſe, gives the objects of the ſame ſenſe diſtinct appellations; calling one colour green, another blue; one taſte ſweet, and another bitter, *&c.* whence men have been induced to frame a long catalogue of ſuch things, as, for their relation to our ſenſes, we call ſenſible qualities. And, becauſe we have been converſant with them before we had the uſe of reaſon; and becauſe the mind of man is inclin'd to conceive almoſt every thing (even privations, as blindneſs, death, *&c.*) under the notion of a true entity, or ſubſtance; we have been, from our infancy, apt to imagine, that theſe ſenſible qualities are real beings in the objects they denominate; and have the faculty and power to work particular things; as gravity has a power to ſtop the

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the motion of a bullet ſhot upwards, and carry that ſolid globe of matter towards the center of the earth: whereas, indeed, there is in the body, to which theſe ſenſible qualities are attributed, nothing real and phyſical, but the ſize, ſhape, and motion, or reſt, of its component particles, together with that texture of the whole, which reſults from their being contrived as they are. Nor is it neceſſary they ſhould have in them any thing more, like to the ideas they excite in us; thoſe ideas being either the effects of our prejudices or inconſiderateneſs, or elſe to be derived from the relation that happens betwixt thoſe primary accidents of the ſenſible object, and the peculiar texture of the organ it affects; as, when a pin, being run into the finger, cauſeth pain, there is no diſtinct quality in the pin, anſwerable to what we are apt to fancy in pain; but the pin, in itſelf, is only ſlender, ſtiff, and ſharp, and by thoſe qualities, happens to make a ſolution of continuity in the organ of feeling, upon which, by reaſon of the fabric of the body, and the intimate union of the ſoul with it, there ariſeth that troubleſome kind of perception, which we call pain. PHYSICS.

6. But here a difficulty will ariſe; for ſince we explain colours, odours, and the like ſenſible qualities, by a relation to our ſenſes; it ſeems evident, that they have an abſolute being, independent of us: thus ſnow (for inſtance) would be white, and a glowing coal hot, tho' there were no man, or any other animal in the world: and it is plain, that bodies do not, by their qualities alone, affect our ſenſes, but even inanimate things too; as a fire-coal will not only burn a man's hand, but would likewiſe heat wax, and thaw ice, tho' all the men, and ſenſitive beings in the world, were annihilated. To clear this difficulty, I do not ſay, there are no other accidents in bodies, than colours, odours, and the like; for it hath already been ſhewn, that there are more ſimple and primitive affections of matter, from which theſe ſecondary qualities proceed; and that the operations of bodies upon one another, reſult from the ſame, we ſhall ſee hereafter. Nor do I ſay, that all qualities of bodies are directly ſenſible, but obſerve, that when one body works upon another, the knowledge we have of their operation, proceeds either from ſome ſenſible quality, or ſome more general affection of matter; as motion, reſt, or texture, generated or deſtroy'd in one of them: elſe it is hard to conceive, how we ſhall come to diſcover what paſſes betwixt them. And we muſt not look upon every diſtinct body, that affects the ſenſes, as a bare lump of matter of the bigneſs, and external ſhape, it appears; many of them having their parts curiouſly contrived, and moſt of them, perhaps, in motion too. Nor muſt we ſuppoſe the univerſe that ſurrounds us, a moveleſs and undiſtinguiſh'd heap of matter, but a great engine; which, having either no vacuity, or none that is conſiderable betwixt its known parts, the actions of particular bodies upon one another, muſt not be barely eſtimated, as if two portions of matter, of their bulk and figure, were placed in ſome imaginary ſpace beyond the world; but as being ſituate in the world, conſtituted as it now is, and conſequently as having their action upon each other liable to be promoted, hindred, or modified by the actions of other bodies. A ſmall force apply'd to move the index of a clock to the figure xii. will make

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PHYSICS. the hammer often ſtrike with force againſt the bell, and cauſe much more commotion among the wheels and weights, than a far greater force would do, if the texture and contrivance of the clock did not largely contribute to the production of ſuch an effect. And in agitating water into froth, the whiteneſs would never be produced by that motion, were not the ſun, or other lucid body, to ſhine upon that aggregate of ſmall bubbles, and enable them confuſedly to reflect numberleſs little, contiguous, lucid images to the eye. Thus, giving a concave figure to a large metalline ſpeculum, would never enable it to fire wood, and to melt down metals, if the ſun-beams were not, by means of that concavity, thrown to a point. And to ſhew, by an eminent inſtance, what various, and different effects, the ſame action of a natural agent may produce, according to the ſeveral diſpoſitions of the bodies it works upon; in two eggs, the one prolific, the other not, the ſenſes can, perhaps, find no difference before incubation; yet, theſe bodies, outwardly alike, ſo differ in the internal diſpoſition of their parts, that if both be expoſed to the ſame degree of heat; that heat will change the one into a putrid and fetid ſubſtance, and the other into a chick. Farther, I deny not, that bodies may be ſaid to have thoſe qualities, we call ſenſible, tho' there were no animals in the world; for a body, in that caſe, may differ, from thoſe which are now quite deſtitute of quality, in having ſuch a diſpoſition of its conſtituent corpuſcles, that in caſe it were duly apply'd to the organ of ſenſe of an animal, it would produce ſuch a ſenſible quality, which a body of another texture would not: thus, if there were no animals, there would be no ſuch thing as pain; yet a pin may, upon account of its figure, be fitted to cauſe pain, in caſe it were moved againſt a man's finger; whereas a bullet, or other blunt body, moved againſt it with no greater force, would cauſe no ſuch perception. Thus ſnow, tho', were there no lucid body, nor organ of ſight in the world, it would exhibit no colour, hath a greater diſpoſition than a coal, or ſoot, to reflect light, when the ſun ſhines upon all three. And ſo a lute is in tune, whether it be actually plaid upon or no, if the ſtrings be all ſo duly ſtretched, that it would appear to be in tune, in caſe it were touched. But, if a pin ſhould be thruſt into a man's finger, both a while before and after his death, tho' the pin be as ſharp at one time as at the other, and makes in both caſes a like ſolution of continuity; yet, in the former caſe, the action of the pin will produce pain, and not in the latter; becauſe in this, the pricked body wants the faculty of perception: ſo, were there no ſenſitive beings, thoſe bodies that are now the objects of our ſenſes, would be diſpoſed, indeed, to yield colours, taſtes, and the like; but actually poſſeſs only thoſe more general properties of bodies, figure, motion, texture, *&c.* To illuſtrate this farther: ſuppoſe a man ſhould beat a drum at ſome diſtance from the mouth of a cave, conveniently ſituated to reflect the ſound of it; tho' men will preſently conclude, that cave to have an echo, and be apt to fancy upon that account, ſome real property in the place, to which the echo is ſaid to belong; and tho' the ſame noiſe made in many of the neighbouring places, would not be reflected to the ear, and conſequently manifeſt thoſe places to have no echoes; yet,

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to ſpeak phyſically, this peculiar quality or property we fancy in the cave, PHYSICS. is nothing but the hollowneſs of its figure, whereby it is ſo diſpoſed, when the air beats againſt it, as to reflect the motion towards the place whence it began; for here intervenes only the figure of one body, and the motion of another; tho', if a man's ear chance to be in the way of theſe motions of the air, forwards and backwards, it gives him a perception of them, which he calls ſound: and, becauſe theſe perceptions, which are ſuppoſed to proceed from the ſame percuſſion of the drum, and thereby of the air, are made at diſtinct times one after another; that hollow body, from whence the laſt ſound appears to come to the ear, is imagined to have a peculiar faculty, upon account whereof we ſay, that ſuch a place hath an echo. And tho' one body often ſeems to produce in another ſeveral ſuch qualities as we call ſenſible, which therefore appear not to require any reference to our ſenſes; I conſider, that when one inanimate body works upon another, there is nothing really produced by the agent in the patient, except ſome local motion of its parts, or ſome change of texture conſequent upon that motion; and ſo if the patient comes to have any ſenſible quality, that it had not before, it acquires it upon the ſame account with other bodies: and it is but a conſequent to this mechanical change of texture, that by means of its effects upon our organs of ſenſe, we are induced to attribute this or that ſenſible quality to it. As in caſe a pin ſhould chance, by ſome inanimate body, to be driven againſt a man's finger, that which the agent doth, is but to put a ſharp and ſlender body into ſuch a kind of motion; and that which the pin doth, is to pierce into the body it meets with, not hard enough to reſiſt its motion: ſo that, upon this, there ſhould enſue ſuch a thing as pain, is but a conſequent, that ſuperadds nothing of real to the pin, which occaſions that pain. Thus, if a piece of tranſparent ice be, by the fall of ſome hard body, broken into a groſs powder that looks whitiſh, the falling body doth nothing to the ice, but break it into very ſmall fragments, that lie confuſedly upon one another; tho' by reaſon of the fabric of the world, and of our eyes, there will, in the light, enſue, upon this comminution, ſuch a kind of plentiful reflection of the incident rays to our eyes, as we call whiteneſs: and when the ſun, by thawing this broken ice, deſtroys the whiteneſs of that portion of matter, and makes it tranſparent, which it was not before, it only alters the texture of the component parts, by putting them into motion, and thereby into a new order; in which, by reaſon of the diſpoſition of the pores intercepted betwixt them, they reflect but few of the incident rays of light, and tranſmit the greater part. Thus when a rough piece of ſilver is burniſhed, that which is really done, is but the depreſſion of the little protuberant parts into one level with the reſt of the ſuperficies; tho' upon this mechanical change of the texture of the ſuperficial parts, we ſay, that it hath loſt the quality of roughneſs, and acquir'd that of ſmoothneſs, becauſe the little extancies, by their figure, before reſiſted, a little, the motion of our fingers, and grated upon them, when now the fingers meet with no ſuch reſiſtance. It is true, the fire thaws ice, and alſo makes wax flow, and enables it to burn a man's hand; yet this doth not neceſſarily argue any inherent

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PHYSICS. rent quality of heat in it, distinct from the power it hath of putting the small parts of the wax into such a motion, as makes their agitation surmount their cohesion; which motion, together with their gravity, is enough to make them, for a season, constitute a fluid. *Aqua fortis*, without any sensible heat, will give camphire the form of a liquor distinct from itself; as a strong fire will, also, make camphire fluid. And I know a liquor, into which certain bodies being put, when both itself and they are actually cold, will not only speedily dissipate many of their parts into smoak, but leave the rest black, and burnt almost like a coal. So that, tho' we suppose the fire to do no more, than variously and briskly agitate the insensible parts of wax; this may suffice to make us think the wax endowed with a quality of heat; because, if such an agitation be greater than that of our organs of touch, 'tis enough to produce in us the sensation we call heat; which is so much a relative to those organs, that we see the same luke-warm water, whose corpuscles are only moderately agitated by the fire, will appear hot to one hand, if that be very cold, and cold to the other, in case that be very hot, tho' both of them belong to the same man. In short, if we fancy any two of the bodies about us, to have nothing to do with any other body in the universe, it is not easy to conceive, either how one can act upon the other, but by local motion, or how by motion it can do any more, than put the parts of the other body into motion too, and thereby produce in them a change of situation and texture, or of some other of its mechanical affections: tho' this passive body, being placed among others, in a world constituted as ours is now, and being brought to act upon the most curiously contriv'd organs of animals, may, upon both these accounts, exhibit many different phenomena; which, tho' we look upon them as distinct qualities, are but the effects of the universal properties of matter; and may be deduced from the size, shape, motion, (or rest) posture, order, and the resulting texture of its insensible parts. And therefore, tho' for shortness, I shall not scruple to use the word, qualities; since it is already generally received, I must be understood to mean it in a sense suitable to this doctrine *.

Form, what. 7. We may next consider, that men having taken notice of certain accidents associated in some bodies, and other conventions of accidents in others, they, for conveniency, and the more expeditious expression of their conceptions, agreed to distinguish them into several sorts; which they call genders, or species, according as they referred them, either upwards to a more comprehensive sort of bodies, or downwards to a narrower species, or to individuals. Thus, observing many bodies to agree in being fusible, malleable, heavy, *&c.* they gave to that sort of body the name of metal; which is a genus, in reference to gold, silver, lead, and but a species in reference to that sort of mix'd bodies called fossils; this superior genus comprehending both metals, stones, and other concretions, though itself

* For a more full account of this matter, see Mr. *Locke's* Essay on human understanding, from book 2. ch. 23. to book 3. ch. 5.

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be but a ſpecies in reſpect of mix'd bodies. Now, when a body is referr'd to any particular ſpecies; becauſe men have agreed to ſignify all the eſſentials requiſite to conſtitute ſuch a body, by one name, moſt writers have been apt to think, that, beſides the common matter of all bodies, there is but one thing that diſcriminates it from other kinds, and makes it what it is; and this, for brevity-ſake, they call form; which, becauſe all the qualities, and other accidents of the body, muſt depend on it, they alſo imagine to be a very ſubſtance, and, indeed, a kind of ſoul, that, united to the groſs matter, with it compoſes a natural body, and acts by the ſeveral qualities, to be found therein, which men uſually aſcribe to the creature ſo compoſed. But aſk a man what gold is, if he cannot ſhew you a piece, and tell you this is gold, he will deſcribe it as a body that is extremely ponderous, very malleable, ductile, fuſible, yet fixed in the fire, and of a yellowiſh colour; and if you offer to put off to him a piece of braſs for a piece of gold, he will preſently refuſe it; and tell you, that, though your braſs be colour'd like that, it is not ſo heavy, ſo malleable, nor will, like gold, reſiſt the fire, or *Aqua fortis*. And if you aſk men, what they mean by a ruby, nitre, or pearl, they will ſtill make you ſuch anſwers, from whence you may clearly perceive, that whatever we talk, in theory, of ſubſtantial forms, yet that, upon account of which, we really diſtinguiſh any one body from another, and refer it to this or that ſpecies of bodies, is nothing but an aggregate or convention of ſuch accidents, as moſt men, by a kind of agreement, think neceſſary, or ſufficient to make a portion of the univerſal matter belong to a determinate genus or ſpecies of natural bodies. The maintaining it poſſible to tranſmute the ignobler metals into gold, argues, that if a man could bring any parcel of matter to be yellow, malleable, ponderous, and to have a concurrence of all thoſe accidents, by which men try true gold from falſe, they would, without ſcruple, take it for true gold. And, indeed, ſince to every determinate ſpecies of bodies, there belongs more than one quality, there needs no more ſufficiently to diſcriminate any one kind of bodies, from all others in the world, not of that kind. Tho' ſpheres and parallelopipeds differ but in ſhape, yet this difference alone is the ground of ſo many others, that *Euclid*, and other geometricians, have demonſtrated many properties of the one, which in no wiſe belong to the other. And it would be thought a man's own fault, if he could not diſtinguiſh a needle from a file, or a key from a pair of ſciſſars; tho' theſe being all made of iron, and differing but in bigneſs and ſhape, are leſs remarkably unlike, than natural bodies; the moſt part of which differ from each other in many more accidents than two. Nor need we think, that qualities being but accidents, they cannot be eſſential to a natural body: for accident is ſometimes oppoſed to ſubſtance, and ſometimes to eſſence; and tho' an accident can be but accidental to matter, as it is a ſubſtantial thing, yet it may be eſſential to a particular body; as tho' roundneſs is but accidental to braſs, yet it is eſſential to a braſs ſphere; becauſe, tho' the braſs were deſtitute of ſphericity, it would ſtill be a corporeal ſubſtance; yet, without that roundneſs, it could not be

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PHYSICS. a ſphere: wherefore, ſince an aggregate of qualities is enough to make the portion of matter, wherein it is found, what it is, and denominate it of a determinate ſort of bodies; and ſince thoſe qualities themſelves, proceed from the more primary and univerſal affections of matter, *viz.* bulk, ſhape, motion, or reſt, and the texture thence reſulting; why may not the form of a body, made up of thoſe qualities, united in one ſubject, likewiſe conſiſt in ſuch a convention of the mechanical properties of matter, as is neceſſary to conſtitute a body of that determinate kind? And ſo, though I ſhall, for brevity-ſake, retain the word form; yet I would be underſtood to mean by it, not a real ſubſtance, diſtinct from matter, but only the matter itſelf of a natural body, conſider'd with its peculiar manner of exiſtence; which, I think, may be properly called, either its ſpecifical or denominating ſtate, or its eſſential modification; or, to expreſs it in one word, its ſtamp: for ſuch a convention of accidents, is ſufficient to perform the offices neceſſarily required in what men call a form; ſince it renders the body what it is, making it appertain to a determinate ſpecies, and diſcriminating it from all other ſpecies of bodies whatſoever. It is, I know, ſaid by ſome, that the form of a body ought to be the principle of its operation; and we ſhall hereafter conſider, in what ſenſe this is to be admitted, or rejected. In the mean time, it may ſuffice, that even the vulgar philoſophy acknowledges, that natural things, for the moſt part, operate by their qualities; and how great the power may be, which a body can exerciſe by virtue of a ſingle quality, will appear by the various effects which fire produces by its heat. And if ſeveral active qualities convene in one body, (as that which I mean by form, uſually comprizes ſeveral of them) how great things may be thereby performed, might be gueſs'd from what we ſee done with ſome engines, by virtue of thoſe accidents, the ſhape, ſize, motion, and contrivance of their parts. But, beſides ſuch operations, as proceed from the eſſential modification of the matter of the body, conſider'd as one intire corporeal agent, it may, in ſeveral caſes, have other operations, upon account of thoſe particular corpuſcles, which, tho' they concur to compoſe it, and are, in regard of the whole, conſider'd but as its parts, may yet retain their own particular nature, and many peculiar qualities. Thus in a watch, beſides the office it performs as ſuch, the ſeveral parts whereof it conſiſts, as the ſpring, the wheels, the ſtring, *&c.* may have each its peculiar bulk, ſhape, and other attributes; upon account of one or more of which, the wheel, ſpring, *&c.* may do other things, than what it merely performs as a conſtituent part of the watch. And ſo in the milk of a nurſe, who hath taken a potion ſome hours before ſhe gives ſuck; tho' the corpuſcles of the purging medicine appear not, to ſenſe, diſtinct from the other parts of the milk, which, in far greater numbers, concur with them, to conſtitute that white liquor; yet theſe purgative particles, that ſeem to be but part of the matter whereof the milk conſiſts, ſo far retain their own nature, and qualities, that, being ſucked in with the reſt, by the infant, they quickly diſcover themſelves by purging him.

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Generation and corruption.

8. It remains that we declare, what is to be meant by generation, corruption, and alteration. In order whereto, we may conſider; firſt, that there are in the world numberleſs particles of matter, each of which is too ſmall to be ſingly ſenſible; which, being intire and undivided, muſt needs both have its determinate ſhape, and be very ſolid; ſo that, tho' it be mentally diviſible, yet, by reaſon of its ſmallneſs, and ſolidity, nature ſcarce ever actually divides it: and ſuch particles might, in this ſenſe, be called *minima*, or *prima naturalia* *. Secondly, there are alſo multitudes of corpuſcles, which are made from the coalition of ſeveral of the former *minima naturalia*, whoſe bulk is ſo ſmall, and their adheſion ſo cloſe, that each of theſe little primitive concretions, or cluſters of particles, is ſingly below the diſcernment of ſenſe; and tho' not abſolutely indiviſible by nature into the *prima naturalia* that compoſed it, or, perhaps, into other little fragments; yet they very rarely happen to be actually diſſolved, or broken; but remain intire in a great variety of ſenſible bodies, and under various forms, or diſguizes. Thus, even groſſer and more compound corpuſcles, may have ſuch a permanent texture: for quick-ſilver may be turned into a red powder, a malleable body, or a fugitive ſmoke; and diſguized by many other ways, and yet remain true and recoverable mercury. And theſe are, as it were, the ſeeds, or immediate principles of many ſorts of natural bodies; *viz.* earth, water, ſalt, *&c.* and, tho' ſingly inſenſible, they become capable, when united, to affect the ſenſe. If good camphire be kept a while in pure ſpirit of wine, it will be thereby reduced into ſuch little parts, as totally to diſappear in the liquor, without making it leſs clear than fair water; yet, if into this mixture, you pour a competent quantity of water, in a moment the ſcatter'd corpuſcles of the camphire will, by re-uniting themſelves, become white, and viſible, as before. Thirdly, as well each of the *minima naturalia*, as each of the primary cluſters, having its own determinate bulk and ſhape, it muſt always happen, when theſe come to adhere to one another, that the ſize, and often, that the figure of

* "It ſeems probable to me," ſays Sir *Iſaac Newton*, "that God, in the beginning, formed matter into ſolid, maſſy, hard, impenetrable, moveable particles, of ſuch "fizes and figures, and with ſuch other properties, and in ſuch proportion to ſpace, as "moſt conduced to the end for which he formed them; and that theſe primitive particles, being ſolids, are incomparably harder "than any porous bodies compounded of them; even ſo hard, as never to wear, or break in "pieces; no ordinary power being able to divide what God himſelf made one in the "firſt creation. While theſe particles continue entire, they may compoſe bodies of "one and the ſame nature, and texture, in "all ages: but ſhould they wear away, or break in pieces, the nature of things depending on them would be changed. Water and earth, compoſed of old worn particles, and fragments of particles, would not be of the ſame nature and texture now with water and earth, compoſed of entire particles in the beginning. And therefore, that nature may be laſting, the changes of corporeal things are to be placed only in the various ſeparations, and new aſſociations and motions of theſe permanent particles; compound bodies being apt to break, not in the midſt of ſolid particles, but where theſe particles are laid together, and only touch in a few points." *Newton. Optic.* p. 375, 376.

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PHYSICS. the corpuſcle, compos'd by their juxta-poſition and coheſion, will be changed; and not ſeldom too, the motion of the one, the other, or both, will receive a new tendency, or be alter'd as to its velocity, or otherwiſe: and the like will happen, when the corpuſcles, that compoſe a cluſter of particles, are disjoined, or part of the little maſs is broken off. And, whether any thing of matter be added to a corpuſcle, or taken from it, in either caſe the ſize of it muſt neceſſarily be altered, and, for the moſt part, the figure will be ſo too; whereby it will both acquire a congruity to the pores of ſome bodies, and become unfit for thoſe of others; and conſequently be qualified to operate on ſeveral occaſions, much otherwiſe than before. Fourthly, when many of theſe inſenſible corpuſcles come to be aſſociated into one viſible body, if moſt of them be put into motion, from what cauſe ſoever the motion proceeds, that itſelf may produce great changes, and new qualities in the body they compoſe: for motion may do this even when it makes no viſible alteration in the body; as air put in a current, acquires a new name, and is called wind, and, to the touch, appears far colder, than the ſame air, not formed into a ſtream; and iron, by being briſkly rubbed againſt wood, or other iron, hath its ſmall parts ſo agitated, as to feel hot. This motion, alſo, frequently makes viſible alterations in the texture of the body, into which it is received; for the moved parts always endeavour to communicate their motion, or ſome degree of it, to parts, which before were either at reſt, or otherwiſe moved; and, often, the ſame moved parts thereby either disjoin, or break ſome of the corpuſcles they hit againſt; and ſo change their bulk, or ſhape, or both; and either drive ſome of them quite out of the body, and, perhaps, lodge themſelves in their places, or elſe aſſociate them with others anew; whence it uſually follows, that the texture is, for a while at leaſt, much altered. Thus water, by loſing the wonted agitation of its parts, acquires the firmneſs and brittleneſs we find in ice; and wants much of the tranſparency it had when fluid. Thus, alſo, by very hard rubbing two pieces of reſinous wood againſt one another, we may make them throw off many of their looſer parts into ſteams, and viſible ſmoke; and, if the attrition be duly continued, cauſe that commotion ſo to change the texture of the whole, as afterwards to turn the ſuperficial parts into a kind of coal. And milk, eſpecially in hot weather, will, by the inteſtine languid motions of its parts, be, in a ſhort time, turned into a thinner ſort of liquor, and into cream; the latter whereof, will, by being barely agitated, ſoon turn into that unctuous and conſiſtent body we call butter, and into a thin, fluid, and ſour liquor. In like manner, by bruiſing fruit, its texture is commonly ſo changed, that the bruiſed part ſoon becomes of a different nature from the ſound; and of another colour, taſte, ſmell, and conſiſtence. So that local motion hath, of all other affections of matter, the greateſt ſhare in the alteration and modification thereof; ſince it is not only the grand efficient among ſecond cauſes, but is alſo, frequently, one of the principal things, that conſtitutes the form of bodies; as when two ſticks are fired by long and vehement attrition, local motion is not only that which kindles the wood, and ſo, as an efficient, produces the fire, but that, which principally concurs

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curs to give the produced ſtream of ſhining matter the name and nature of flame; and thus it, likewiſe, concurs, to conſtitute all fluid bodies. Fifthly, Since it is from the ſize, ſhape, and motion of the ſmall parts of matter, and the texture that reſults from the manner of their being diſpoſed in any body, that the colour, odour, taſte, and other qualities of that body, are to be derived; it will be eaſy to judge ſuch changes poſſible, as may account for the generation and corruption of bodies, from the convention, diſſolution, and the alterations of them, by the tranſpoſition of their conſtituent particles. PHYSICS.

And hence will eaſily flow the doctrine of generation, corruption, and alteration. For if in a parcel of matter there happen ſuch a concurrence of all thoſe accidents, as men, by tacit agreement, have thought neceſſary and ſufficient to conſtitute any one determinate ſpecies of things; then a body belonging to that ſpecies is generated *de novo*. Not that there is, really, any thing ſubſtantial produced, but that thoſe parts of matter, which, indeed, pre-exiſted in other diſpoſitions, are now brought together after a manner, requiſite to entitle the body which reſults from them, to a new denomination, and make it appertain to ſuch a determinate ſpecies of natural bodies; ſo that no new ſubſtance is produced in generation, only that, which was pre-exiſtent, obtains a new modification, or manner of exiſtence. Thus when the ſpring, wheels, ſtring, balance, index, *&c.* neceſſary to a watch, are ſet together in the order requiſite to make ſuch a little engine as ſhall mark the hours, a watch is ſaid to be made; tho' none of the parts are produced anew, but 'till then the divided matter was not contrived and put together, in the manner requiſite to conſtitute the thing we call a watch. And ſo, when ſand and aſhes are well melted together, and ſuffer'd to cool, there is generated, by the colliquation, that ſort of concretion, we call glaſs; tho' its ingredients were both pre-exiſtent, and do, but by their aſſociation, obtain a new manner of exiſting together. And, as a body is ſaid to be generated, when it firſt appears clothed with all thoſe qualities, upon account whereof men call ſome bodies ſtones, others metals, others ſalts, *&c.* ſo when a body comes to loſe all or any of thoſe accidents that are eſſential, and neceſſary to conſtitute ſuch a body, it is then ſaid to be corrupted or deſtroy'd; and is no more a body of that kind, but loſes the title to its former denomination; tho' nothing corporeal or ſubſtantial periſhes in this change, only the eſſential modification of the matter is deſtroy'd; and tho' the body be ſtill a body, yet it is no longer ſuch a body as before, but periſheth in the capacity of a body of that kind. Thus, if a ſtone, falling upon a watch, break it to pieces; as, when the watch was made, there was no new ſubſtance produced, all the material parts being pre-exiſtent ſomewhere or other; ſo, not the leaſt part of the ſubſtance of the watch is loſt, but only diſplaced and ſcattered; yet that portion of matter ceaſeth to be a watch. Thus, when ice comes to be thawed in cloſe veſſels, tho' the corruption be produced only (for ought appears) by introducing a new motion and diſpoſition into the parts of the frozen water, yet it thereupon ceaſeth to be ice, tho' it remains as much water, and, conſequently, as much a body, as before it was frozen,

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PHYSICS. or thawed. Theſe, and the like examples, will teach us how to underſtand that common axiom of naturaliſts, *corruptio unius eſt generatio alterius, & è contra*; for, ſince it is acknowledged on all hands, that matter cannot naturally be annihilated; and, ſince there are ſome properties, as ſize, ſhape, motion, *&c.* that are inſeparable from the actual parts of matter; ſince alſo the coalition of any competent number of theſe parts is ſufficient to conſtitute a natural body, endowed with ſeveral ſenſible qualities; the ſame agents, that ſhatter the frame, and deſtroy the texture of one body, will, by ſhuffling them together, and diſpoſing them after a new manner, neceſſarily bring them to conſtitute ſome new ſort of bodies: as the ſame thing, that, by burning, deſtroys wood, turns it into flame, ſoot, and aſhes. Only I doubt, whether the axiom holds generally true, if it be meant, that every corruption muſt end in the generation of a body, belonging to ſome particular ſpecies of things, unleſs we take powders and fluid bodies, indefinitely, for ſpecies of natural bodies; ſince it is plain, there are multitudes of vegetables, and other concretions, which, when they rot, do not turn into worms, but either into ſome ſlimy or watry ſubſtance, or elſe crumble into a kind of duſt or powder, which, tho' eſteem'd the earth, whereinto rotten bodies are, at length, reſolved, is very far from being of an elementary nature, but as yet remains a compound body, retaining ſome qualities; whence, often, the duſt of one ſort of plant, or animal, differs much from that of another.

To this account of the corruption of bodies, we may add, that their putrefaction is but a peculiar kind of ſlow corruption, which happens to them, for the moſt part, by means of the air, or ſome other ambient fluid, penetrating their pores, and, by its agitation, changing the texture, and, perhaps too, the figure of the corpuſcles that compoſe them; whence the body, thus changed, acquires qualities unſuitable to its former nature, and generally, offenſive to our ſenſes. For I obſerve, that medlars, tho' they acquire, in length of time, the colour and ſoftneſs of rotten apples, and other putrefied fruit; yet, becauſe their taſte is not then harſh as before, we call that ripeneſs in them, which otherwiſe we ſhould call rottenneſs. And tho' upon the death of a beaſt, we generally call that change, which happens to the fleſh or blood, putrefaction; yet we ſay not ſo of what happens to thoſe parts of the ſame animal, whereof muſk is made, becauſe that has a grateful ſcent. And we ſee, that ſome men, who are pleaſed with rotten cheeſe, think it not to have degenerated, but to have now attained its beſt ſtate. But as a body ſeldom acquires, by generation, no other qualities, than juſt ſuch as are abſolutely neceſſary to rank it in the ſpecies that denominates it; there are in moſt bodies ſeveral other qualities, that may be preſent or abſent without eſſentially changing the ſubject: thus water may be clear or muddy, ſweet or fetid, and ſtill remain water; butter may prove white or yellow, ſweet or rancid, conſiſtent or fluid, and ſtill be butter. Whenever, therefore, a parcel of matter acquires or loſes a quality, that is not eſſential to it, that acquiſition or loſs is diſtinctly called alteration; and even generation and corruption, according to this doctrine, are but ſeveral kinds of alteration, taken in a large ſenſe.

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And here we may take notice of the fertility and extent of the mechanical hypotheſis; for ſince, according to our doctrine, the world we live in, is not a moveleſs or indigeſted maſs of matter, but an engine, wherein the greateſt part of the common matter of all bodies is always in motion; and wherein bodies are ſo cloſe ſet by one another, that they have either no vacuities betwixt them, or but few and very ſmall ones; and ſince, according to us, the various manner of the coalition of ſeveral corpuſcles into one viſible body, is enough to give them a peculiar texture, and thereby fit them to exhibit many ſenſible qualities, and to become a body, ſometimes of one denomination, and ſometimes of another; it will naturally follow, that from the various occurſions of thoſe innumerable ſwarms of little bodies, that are moved about in the world, there muſt be many fitted to ſtick to one another, and ſo compoſe concretions; many disjoined from one another, and agitated apart; and multitudes alſo, that will be driven to aſſociate themſelves, now with one body, and again with another. And, if we, alſo, conſider on the one ſide, that the ſizes of the ſmall particles of matter may be very various, and their figures almoſt innumerable; that if a parcel of matter happen to ſtick to one body, it may chance to give it a new quality; and, if it adhere to another, or hit againſt ſome of its parts, conſtitute a body of a new kind; or, if a parcel of matter be ſtruck off from another, it may barely, by that, leave it, and itſelf become of a different nature from that it had before: if, I ſay, we conſider theſe things, it will not be hard to conceive, that there may be an incomprehenſible variety of aſſociations and textures of the minute parts of bodies, and conſequently, a vaſt multitude of portions of matter endowed with many different qualities deſerving diſtinct appellations; tho' for want of care and proper words, men have not yet taken ſo much notice of their leſs obvious varieties, as to ſort them, as they deſerve, and give them diſtinct and proper names. So that tho' I would not ſay, any thing may immediately be made of every thing, as a gold ring of a wedge of gold, or oil, or fire, of water; yet, ſince bodies having but one common matter, can be differenced but by accidents, which ſeem, all of them, the effects and conſequence of local motion, 'tis not abſurd to think, that by the intervention of ſome very ſmall addition or ſubſtraction of matter, and of an orderly ſeries of alterations, gradually diſpoſing the matter to be tranſmuted, almoſt any thing may, at length, be made of any thing; as, tho' out of a wedge of gold, one cannot immediately make a ring, yet by either wiredrawing that wedge, by degrees, or by melting it, and caſting a little of it into a mould, the thing may be effected. And ſo, tho' water cannot immediately be tranſmuted into oil, much leſs into fire, yet if you nouriſh certain plants with water alone, till they have aſſimilated a great quantity of it into their own nature, you may, by committing this tranſmuted water to diſtillation, in convenient glaſſes, obtain, beſides other things, much of a true oil, and a black combuſtible coal*.

The extent of this doctrine.

What

* Sir *Iſaac Newton* ſeems to be of opinion, that even groſs bodies are convertible into the fineſt of bodies, light. "The changing "of bodies into light, and light into bodies, "is,

PHYSICS. *Recapitulation* What we would prove, is, at length, this; firſt, that the matter of all natural bodies is a ſubſtance extended and impenetrable. That all bodies thus agreeing in the ſame common matter, their diſtinction is to be taken from thoſe accidents which diverſify it. That motion, not being eſſential to matter, and not originally producible by other accidents, as they are from it, may be look'd upon as the firſt and chief mode or affection of matter. That motion variouſly determined, naturally divides the matter, it belongs to, into actual fragments; and this diviſion, obvious experience manifeſts to have been made into parts exceedingly minute, and very often too minute to be ſingly perceivable by our ſenſes. Whence it neceſſarily follows, that each of theſe minute parts, or *minima naturalia*, (as well as every particular body, made up by the coalition of any number of them) muſt have its determinate ſize, and ſhape; and that theſe three, bulk, figure, and either motion or reſt, are the primary and moſt univerſal modes of the inſenſible parts of matter, conſider'd each of them apart. That when ſeveral of them are conſider'd together, there will neceſſarily follow, both a certain poſition and poſture in regard to the horizon, and a certain order before, behind, or a-ſide of one another; and when many of theſe ſmall parts convene into one body, from their primary affections, and their diſpoſition or contrivance as to poſture and order, there reſults what we call the texture of that body. And theſe are the affections that belong to a body, conſider'd in itſelf, without relation to ſenſitive beings, or to other natural bodies. We would further ſhew, that there being men in the world, whoſe organs of ſenſe are ſo differently contrived, that one is fitted to receive impreſſions from ſome, and another from other ſorts of external objects; the perceptions of theſe impreſſions are differently expreſs'd by words, as heat, colour, ſound, odour; and are commonly imagined to proceed from certain diſtinct and peculiar qualities in the external object, bearing a reſemblance to the ideas, which their action upon the ſenſes excites in the mind; tho' all theſe ſenſible qualities, and the reſt to be met with in the bodies without us, are but the effects or conſequents of the primary affections of matter, whoſe operations are diverſified according to the nature of the organs, or other bodies they affect. That when a portion of matter, either by the acceſs or receſs of corpuſcles, or by the tranſpoſition of thoſe it conſiſted of before, or by any two or all of theſe ways, obtains a concurrence of all the qualities men commonly agree to be neceſſary and ſufficient to denominate the body poſſeſs'd of them, a metal, a ſtone, or the like, and to rank it in any peculiar and determinate ſpecies of bodies; then a body of that denomination is ſaid to be generated. And

" is," ſays that great Philoſopher, " very " conformable to the courſe of nature, " which ſeems delighted with tranſmutati- " ons. Water, which is a very fluid, taſt- " leſs ſalt, ſhe changes by heat into vapour, " which is a ſort of air; and by cold into " ice, which is a hard, pellucid, brittle, " fuſible ſtone: and this ſtone returns into " water by heat; and vapour returns into " water by cold. Earth by heat becomes " fire, and by cold returns into earth. Denſe " bodies, by fermentation, *rariſy into ſe-* " veral ſorts of air; and this air, by fer- " mentation, and ſometimes without it, re- " turns into denſe bodies." See *Newton. Optic.* p. 349, 350.

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this convention of eſſential accidents being taken together for the ſpecific difference that conſtitutes the body, and diſcriminates it from all other ſorts, is by one name, becauſe conſider'd as one collective thing, called its form; which, conſequently, is but a certain character, or a peculiar ſtate of matter, or an eſſential modification. Laſtly, we would ſhow, that a body being capable of many other qualities, beſides thoſe, whoſe convention is neceſſary to make up its form; the acquiſition or loſs of any ſuch quality is termed alteration; as when oil comes to be frozen, change colour, or grow rancid; but that if all, or any of the qualities, reputed eſſential to ſuch a body, come to be loſt or deſtroy'd, ſuch a remarkable change is called corruption; as when oil takes fire, the oil is not ſaid to be altered, but corrupted or deſtroy'd, and fire generated; and that when the body is ſlowly corrupted, and thereby alſo acquires qualities offenſive to our ſenſes, eſpecially the ſmell and taſte, that kind of corruption is called putrefaction; but that nothing ſubſtantial, either in this, or any other kind of corruption, is deſtroy'd, only that particular connexion of the parts, or manner of their co-exiſtence, upon account whereof the matter was term'd a ſtone, or a metal, or belong'd to any other determinate ſpecies of bodies.

SECT. II.

The vulgar doctrine of forms conſider'd.

THE origin of forms, tho' thought the nobleſt, hath yet been found one of the moſt perplexed inquiries in philoſophy, eſpecially as managed by the ſchools. The ſum of the controverſy betwixt us and them, is, whether the forms of natural things be, in generation, educed, as they ſpeak, out of the power of the matter; and, whether theſe forms are true ſubſtantial entities, diſtinct from the other ſubſtantial principle of natural bodies, that is, matter. The reaſons which move me to embrace the negative, are principally theſe. Firſt, I ſee no neceſſity for admitting any ſuch ſubſtantial forms in natural things; matter, and its accidents, being ſufficient to explain as much of the phenomena of nature, as we are likely to underſtand *. In the next place, I ſee no uſe of this puzzling doctrine of ſubſtantial forms in natural philoſophy; nor can imagine how particular phenomena ſhould be explain'd by a principle, whoſe nature is unknown. And, laſtly, I cannot conceive, how forms ſhould be generated, as the peripatetics would have it; nor how the things they aſcribe to them, are conſiſtent with the principles of true philoſophy, or even with what themſelves otherwiſe teach. I know the ſchoolmen here take refuge in an obſcure diſtinction, and tell us, that the power of matter, with regard to forms, is partly eductive, as the agent can make the form out of it, and partly receptive, whereby it can receive the form ſo made: but, ſince thoſe who ſay this, will not allow, that the form of a generated body was actually pre-exiſtent in its matter, or any where elſe, it is hard to conceive how a ſubſtance can be educed out of another

* 'Tis Sir *Iſaac Newton*'s firſt rule in philoſophy, that no other cauſes ſhould therein be admitted, but ſuch as are true, and ſufficient to ſolve the phenomena. *Newton Princip.* p. 357.

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PHYSICS. ſubſtance totally diſtinct in nature from it, without being, before ſuch eduction, actually exiſtent in it. And as for the receptive power of the matter, that but fitting it to receive or lodge a form, when united with it; how can it be intelligibly made appear to contribute to the production of a new ſubſtance, of a quite different nature from that matter, tho' it harbours it when produced? It is plain, that the human body hath a receptive power with regard to the human ſoul, which yet themſelves confeſs, both to be a ſubſtantial form, and not to be educed out of the power of matter. Indeed, if they would admit the form of a natural body to be but a more fine and ſubtile part of the matter, (as ſpirit of wine is of wine, which, upon the receſs thereof, remains no longer wine, but phlegm, or vinegar,) then the eductive power of matter might ſignify ſomething: and ſo it might, if they would allow the form to be but a modification of the matter; for then it would import, that the matter may be ſo ordered or diſpoſed by fit agents, as to conſtitute a body of a particular ſort, and denomination: as the form of a ſphere may be ſaid to lurk potentially in a piece of braſs, becauſe the braſs may, by caſting, turning, or otherwiſe, be ſo figur'd, as to become a ſphere. But this they will not admit, leſt they ſhould make forms to be but accidents; tho' it is, for ought I know, as little intelligible, how, what is educed out of any matter, without being either pre-exiſtent, or any part of the matter, can be a true ſubſtance; as how that roundneſs which makes a piece of braſs become a ſphere, can be a new ſubſtance in it. Nor can they admit the other way of educing a form out of matter, as ſpirit out of wine, becauſe then matter will be corruptible, contrary to their doctrine; and matter and form not be two different and ſubſtantial principles, only one and the ſame, tho' diverſify'd by firmneſs, groſſneſs, *&c.* which are but accidental differences. I know they ſpeak much of the efficacy of the agent upon the matter, in the generation of natural bodies, and tell us ſtrange things of his manner of working. But not to ſpend time in examining thoſe obſcure niceties; I anſwer, in ſhort, that ſince the agent, let him be what he will, is but a phyſical and finite agent; and ſince what way ſoever he works, he can do nothing repugnant to the nature of things; the difficulty with me will ſtill remain. For if the form produced in generation be, as they would have it, a ſubſtance, not before to be found, out of that portion of matter, wherewith it conſtitutes the generated body; either it muſt be produced by refining, or ſubtilizing ſome parts of the matter into form; or elſe, it muſt be produced out of nothing; that is, created. If they allow the firſt, then will the form be indeed a ſubſtance, but not, as they hold it, diſtinct from matter; ſince matter, however ſubtilized, is matter ſtill; as the fineſt ſpirit of wine is as truly a body, as the wine itſelf that yielded it; or as is the groſſer phlegm from which it was extracted. Beſides, the *Peripatetics* teach, that the form is not made of any part of the matter: nor, indeed, is it conceivable, how a phyſical agent can turn a material into an immaterial ſubſtance; eſpecially, matter being, as they themſelves confeſs, as well incorruptible, as ingenerable. But if they will not allow, as they do not, that the ſubſtantial form is made of any thing material, they muſt

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let me believe it produced out of nothing, till they ſhew how a ſubſtance can be otherwiſe produced, that exiſted no where before. And, at this rate, every natural body, of a ſpecial denomination, as gold, marble, nitre, *&c.* muſt not be produced barely by generation, but partly by generation, and partly by creation. And, ſince it is confeſs'd on all ſides, that no natural agent can produce the leaſt atom of matter, 'tis ſtrange they ſhould, in generation, allow every phyſical agent the power of producing a form, which, according to them, is not only a ſubſtance, but a far more noble one than matter, and, thereby, attribute to the meaneſt creatures that power of creating ſubſtances, which the ancient naturaliſts thought too great to be aſcribed to God himſelf; and, therefore, ſome ſchoolmen have derived forms immediately from God: but this is not only to deſert *Ariſtole*, and the *Peripatetic* philoſophy, which they would ſeem to maintain, but to put omnipotence upon working many thouſand miracles every hour, to perform that, in a ſupernatural way, which ſeems the moſt familiar effect of nature in her ordinary courſe. PHYSICS.

And, as the production of forms out of the power of matter, is, for theſe reaſons, incomprehenſible to me; ſo thoſe things which the *Peripatetics* aſcribe to their ſubſtantial forms, are ſome of them ſuch, as I cannot reconcile to my reaſon: for they tell us poſitively, that theſe forms are ſubſtances, yet at the ſame time teach, that they depend upon matter both *in fieri* and *eſſe*, as they phraſe it; ſo that they cannot ſo much as exiſt out of the matter which ſupports them; which is to make them ſubſtances in name, and accidents in reality: for, how can one ſubſtance be ſaid to depend upon another *in fieri*, that is not made of any part of it? The very notion of a ſubſtance, is, to be a ſelf-ſubſiſting entity, or that which needs no other created being to ſupport it, or to make it exiſt. Beſides, as there are but two ſorts of ſubſtances, material and immaterial, a ſubſtantial form muſt appertain to one of them; tho' they aſcribe ſuch things to it, as make it very unfit to be referred to either. To all this I add, that theſe imaginary material forms almoſt as much diſturb the doctrine of corruption, as that of generation: for if a form be a true ſubſtance, really diſtinct from matter, it muſt, as we ſaid, be able to exiſt of itſelf, without any other ſubſtance to ſupport it: as, thoſe I reaſon with confeſs, that the ſoul of man ſurvives the body, it, before death, inform'd: whereas, they will have it, that in corruption the form is quite aboliſhed, and utterly periſhes, as not being capable of exiſting, ſeparated from the matter, whereto it was united. So that here again, what they call a ſubſtance, they make an accident; and beſides, contradict their own vulgar doctrine, that natural things are, upon their corruption, reſolved into the firſt matter; ſince, at this rate, they ſhould ſay, that ſuch things are but partly reſolved into the firſt matter, and partly, either into nothing, or into forms; which being as well immaterial as the ſouls of men, muſt, for ought appears, be alſo, like them, accounted immortal.

I ſhould now proceed to examine the arguments employ'd by the ſchools, to prove their ſubſtantial forms; but becauſe they are rather metaphyſical,

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PHYSICS. or logical, than grounded upon the principles and phenomena of nature, and reſpect rather words than things, I ſhall, very briefly, anſwer only two or three of the moſt plauſible. Firſt, then, they thus argue. *Omne compoſitum ſubſtantiale* (it is hard to engliſh ſuch uncouth terms) *requirit materiam & formam ſubſtantialem, ex quibus componatur: omne corpus naturale eſt compoſitum ſubſtantiale. Ergo, &c.* Now, for brevity ſake, I ſhall here only deny the minor, and deſire the propoſers to prove it. For I know no thing in nature, that is compoſed of matter, and a ſubſtance diſtinct from matter, except man, who alone is made up of an immaterial form, and a human body. If it be urged, that then other bodies cannot be properly called *compoſita ſubſtantialia*, I ſhall, rather than wrangle, give them leave to find out ſome other name for other natural things. But then they argue, in the next place, that, if there were no ſubſtantial forms, all bodies would be but *entia per accidens*, which is abſurd. To this I anſwer, that in the notion many learned men have of an *ens per accidens*, as being that which conſiſts of thoſe things *quæ non ordinantur ad unum*, tho' we do not admit ſubſtantial forms, yet we need not admit natural bodies to be *entia per accidens*; becauſe in them the ſeveral things that concur to conſtitute the body, as matter, ſhape, ſituation, and motion, *ordinantur per ſe, & intrinſicè*, to conſtitute one natural body. But if this anſwer be not ſatisfactory, I add, that I am ſollicitous about what nature hath made things in themſelves, not what a logician or metaphyſician will call them, in the terms of his art; it being much fitter, in my judgment, to alter words to the nature of things, than to affix a wrong nature to things, to accommodate them to a form of words, probably deviſed when the things themſelves were unknown, or not well underſtood, if thought on. Wherefore, I ſhall further only conſider this argument, "if there were no ſubſtantial forms, there could be no ſubſtantial definitions; but the conſequent is abſurd, ſo, therefore, is the antecedent." I reply, that ſince the *Peripatetics* confeſs the forms of bodies to be of themſelves unknown, this argument only concludes, that if we do not admit ſome things, that are not in nature, we cannot build our definitions upon them; nor, indeed, could we, if we ſhould admit ſubſtantial forms, give ſubſtantial definitions of natural things, unleſs we could, alſo, define natural bodies by things that we know not; for ſuch the ſubſtantial forms are confeſs'd to be by the wiſeſt *Peripatetics*, who pretend not to give the ſubſtantial definition of any natural compoſition, except man. But it may ſuffice us to have, inſtead of ſubſtantial definitions, eſſential ones of things; I mean, ſuch as are taken from their eſſential differences, which conſtitute them a particular ſort of natural bodies, and diſtinguiſh them from all thoſe of any other kind,

But for fear arguments of this ſort ſhould not prevail, ſome modern aſſerters of forms have thought fit to add phyſical ones; which may be more to our purpoſe here to conſider. Firſt then, among the phyſical arguments, brought to prove ſubſtantial forms, the principal is taken from the ſpontaneous return of heated water to coldneſs; which effect, ſay they, muſt neceſſarily be aſcribed to the action of the ſubſtantial form, whoſe office it is

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to preſerve the body in its natural ſtate, and, as there is occaſion, to reduce it thereto: which, indeed, might ſeem plauſible, if we were ſure that heated water would grow cold again, without the loſs of any parts more agitated than the reſt, ſuppoſing it to be removed into ſome of the imaginary ſpaces beyond the world; but as the caſe is, I ſee no neceſſity of flying to a ſubſtantial form: for the water we heat, is ſurrounded with our air, ſome veſſel, or other body contiguous to the air; and both the air and water in our climate, are moſt commonly leſs agitated, than the animal juices in our hands, or other organs of touch; which makes us call thoſe fluids cold. Now, when the water is expoſed to the fire, it is thereby put into a new agitation, more vehement than that of the parts of our organs; but when the liquor is removed from the fire, this acquired agitation muſt be gradually loſt, either by the avolation of ſuch fiery corpuſcles, as the *Epicureans* imagine to get into heated water, or by its communicating the agitation of its parts to the contiguous air, or to the containing veſſel, till it have loſt its additional motion, or by the entrance of thoſe frigorific atoms, wherewith (if any ſuch be granted) the air in theſe climates abound, and ſo be reduced to its former temperature: which may as well happen without a ſubſtantial form, as, if a ſhip ſailing ſlowly down a river, ſhould, by a ſudden guſt of wind, blowing with the ſtream, be driven on much faſter than before; for the veſſel, upon the wind's ceaſing, would, without any ſuch internal principle, ſoon return to its former ſlowneſs of motion. So that in this phenomenon, we need not have recourſe to an internal principle; the temperature of the external air, being ſufficient to ſolve it. And, if water be kept in the upper part of a houſe, where the climate is hot, it will, in ſpite of the form, continue far leſs cold, all the ſummer long, than, according to the *Peripatetics*, its nature requires. And, by the doctrine of forms, the fluidity of water muſt proceed as much from its form, as the coldneſs; and yet this ſo far depends upon the temperature of the air, that in *Nova Zembla*, vaſt quantities of water are kept in ſolid ice, all the year long, notwithſtanding the power of a ſubſtantial form to preſerve it fluid; which it will never be made, unleſs by ſuch a temperature of the air, as would itſelf, for ought appears, make it flow again, tho' there were no ſubſtantial form in nature. PHYSICS.

Another argument is, that matter being indifferent to one ſort of accidents as well as another, it is neceſſary there ſhould be a ſubſtantial form, to keep thoſe accidents, which are ſaid to conſtitute it, united with the matter they belong to, and preſerve both them and the body in their natural ſtate; for, ſince it is confeſs'd, that matter hath no appetite to theſe accidents more than to any others, they demand how, without a ſubſtantial form, theſe accidents can be contained and preſerved? To this, it might be ſufficient to object, that the common notions of the natural and preternatural ſtate of bodies, are falſe or ill grounded: but to come cloſe to the argument, I anſwer, that the accidents ſpoken of, are introduced into the matter by the agents or efficient cauſes, whatever they be, producing in it, what we call an eſſential form. And theſe accidents, being once thus introduced

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PHYSICS. troduced into the matter, we need not ſeek for a new ſubſtantial principle to preſerve them there; ſince, by the general law, or common courſe of nature, the matter qualify'd by them, muſt continue in the ſtate wherein ſuch accidents have put it, till by ſome agent or other, it be forced out of it, and ſo diveſted of thoſe accidents: thus in a braſs ſphere, when once the motion of tools, impell'd and guided by the artificer, hath turned a piece of that metal to a globe, there needs no new ſubſtance to preſerve that round figure; ſince the braſs muſt retain it, till it be deſtroy'd by the artificer himſelf, or ſome other agent, able to overcome the reſiſtance of the matter to be put into another figure. And as, when there is no competent deſtructive cauſe, the accidents of a body will, by the law of nature, remain ſuch as they were; ſo if there be, it cannot be pretended, that the ſubſtantial form is able to preſerve all thoſe accidents of a body that are ſaid to flow from it, and to be, as it were, under its care and tuition. If, for inſtance, you expoſe a ſphere, or bullet of lead, to a ſtrong fire, it will quickly loſe its coldneſs, conſiſtence, malleableneſs, colour, flexibility, and ſome other qualities; and all this, in ſpite of any imaginary ſubſtantial form. And tho' upon taking lead from the fire, it is reduced to moſt of its former qualities, yet, that may well be aſcribed to its peculiar texture, and the coldneſs of the ambient air, according to what was ſaid of water, heated and cooled; which temperature of the air is an external thing to the lead: and, indeed, it is but accidental, that the lead, upon refrigeration, regains its former qualities; for, by being expoſed long enough to an intenſe fire, it will be turned into glaſs, and loſe its colour, opacity, malleableneſs, and flexibility, and acquire a reddiſhneſs, a degree of tranſparency, a brittleneſs, and ſome other qualities, that it had not before. And let the ſuppoſed ſubſtantial form do what it can, even when the veſſel is removed from the fire, to reduce or reſtore the body to its natural ſtate and accidents; yet the former qualities will continue loſt, as long as theſe preternatural ones, introduced by the fire, continue in the matter; and, neither the one will be reſtored, nor the other deſtroy'd, till ſome ſufficiently powerful external agent effect the change.

It is, likewiſe, urged, that no reaſon can be aſſign'd, why whiteneſs ſhould be ſeparable from a wall, and not from ſnow, or milk; unleſs we have recourſe to ſubſtantial forms. But in caſe men have agreed to call a thing by ſuch a name, becauſe it hath ſuch a particular quality that diſtinguiſhes it from others, we need go no farther to find a reaſon, why one quality is eſſential to one thing, and not to another. Thus in a braſs ſphere, the figure is that for which we give it the name: and, therefore, tho' you may alter the figure of the matter, yet by that very alteration, the body periſhes in the capacity of a ſphere; tho' its coldneſs may be exchanged for heat, without making it the leſs a ſphere, becauſe it is not for any ſuch quality, but for roundneſs, that a body is called a ſphere. And ſo firmneſs is an inſeparable quality of ice, tho' a particular figure be not; becauſe it is for want of fluidity, that we call any thing ice, which was immediately before a liquor: and, accordingly, tho' whiteneſs were inſeparable from

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ſnow and milk, yet, this would not neceſſarily infer, that there muſt be a ſubſtantial form to make it ſo; for the firmneſs of the corpuſcles that compoſe ſnow, is as inſeparable from it, as the whiteneſs; and yet it is not pretended to be the effect of the ſubſtantial form of the water, but of the exceſs of the coldneſs of the air, which puts the water out of its natural ſtate of fluidity, and into a preternatural one of firmneſs and brittleneſs. And the reaſon why ſnow ſeldom loſes its whiteneſs, but with its nature, ſeems to be, that its component particles are ſo diſpoſed, that the ſame heat of the ambient air, which is fit to turn it into a tranſparent body, is alſo fit to make it fluid; which, when it is become, we no longer call it ſnow, but water: ſo that the water loſes its whiteneſs, tho' the ſnow do not. But if there be a cauſe proper to make a convenient alteration of texture in the ſnow, without melting or reſolving it into water, it may then exchange its whiteneſs for yellowneſs, without loſing its right to be called ſnow; as an eminent writer relates, that in the northern regions, towards the pole, thoſe parcels of ſnow, that have lain very long on the ground, degenerate, in time, into a yellowiſh colour, very different from that pure whiteneſs to be obſerved in the neighbouring ſnow lately fallen. PHYSICS.

But there yet remains an argument for ſubſtantial forms, taken from a ſuppoſed neceſſity there is of thence deriving all the various changes to which bodies are ſubject, the different effects they produce, the preſervation and reſtitution of the ſtate requiſite to each particular body, and the keeping of its ſeveral parts united into one whole. In anſwer to this, we might ſay, that many great alterations may happen to bodies, which ſeem manifeſtly to proceed from their peculiar texture, and the action of outward agents upon them, and of which it cannot be ſhewn, that they would happen otherwiſe, tho' there were no ſubſtantial forms in being: as we ſee that tallow, melted by the fire, loſes its coldneſs, its firmneſs, and its whiteneſs, and acquires heat, fluidity, and ſome tranſparency; but being ſuffered to cool, it preſently exchanges theſe for the former qualities; yet ſeveral of thoſe changes are plainly the effects of the fire, and the ambient air, not of any ſubſtantial form: and it is evident, that fire effects a great variety of changes in qualities, and produces new ones, by its heat, that is, by a modified local motion. I conſider farther, that various operations of a body may be derived from the peculiar texture of the whole, and the mechanical properties of the particular corpuſcles, or other parts that compoſe it. And to the pretence, that a ſubſtantial form is requiſite to keep the parts of a body united, without which it would not be one entire body; I anſwer, that the contrivance of parts conveniently figured, and, in ſome caſes, their juxta-poſition may, without the aſſiſtance of a ſubſtantial form, be ſufficient. A pear grafted upon a thorn, or a plumb inoculated upon an apricock, will bear good fruit, and grow up with the ſtock, as if they both made but one tree, and were animated by the ſame common form; tho' both the ſtock, and the inoculated plant, have each its own form, as may appear by the different leaves, fruits, and ſeeds they bear. And even vegetation, and the diſtribution of aliments, are, in ſuch caſes, well

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PHYSICS. well made, tho' the nouriſhed parts of the total plant, have not one common ſoul or form; which is yet more remarkable in miſletoe, growing upon old hazle-trees, crab-trees, &c. in which the miſletoe often differs very widely from that kind or plant on which it thrives and proſpers. And for the durableneſs of the union betwixt bodies, that a ſubſtantial form is not requiſite to procure it, I have been induced to think by conſidering, that ſilver and gold, being barely mixed by fuſion, will have their minute parts more cloſely united, than thoſe of any plant or animal we know of. And there is ſcarce any natural body, wherein the form makes ſo ſtrict, durable, and indiſſoluble an union of the parts it conſiſts of, as that, which in the factitious concrete, we call glaſs, ariſes from the bare commixture of the corpuſcles of ſand, with thoſe ſaline ones, wherewith they are melted by the violence of the fire: and the like may be ſaid of the union of the proper accidents of glaſs with the matter of it, and betwixt one another.

It is ſtill farther alledg'd in behalf of ſubſtantial forms, that theſe being in natural bodies, the true principles of their properties, and conſequently of their operations, that natural philoſophy muſt needs be very imperfect, which rejects them. But, if there were, in every natural body, ſuch a thing as a ſubſtantial form, from which all its properties and qualities immediately flow; ſince we ſee, that the actions of bodies upon one another, are immediately performed by their qualities or accidents; it would ſcarce be poſſible to ſolve many of the explicable phenomena of nature, without having recourſe to them: and it would be ſtrange, if many of the abſtruſer phenomena were not explicable by them only. Yet, indeed, almoſt all the rational accounts to be met with of difficult phenomena, are given by ſuch, as either do not acknowledge, or, at leaſt, do not take notice of ſubſtantial forms. And, it is evident, by the clear ſolutions of many phenomena in ſtatics, and other parts of mechanics, and eſpecially in hydroſtatics, and pneumatics, that they may be ſatisfactorily ſolved without employing a ſubſtantial form. On the other ſide, I do not remember, that either *Ariſtotle* himſelf, or any of his followers, have given an intelligible ſolution of any one phenomenon of nature, by the help of ſubſtantial forms: and as their nature is unknown to us, to explain any effect by them, muſt be to declare *ignotum per ignotius*, or, at leaſt, *per æque ignotum*. For to ſay, that ſuch an effect proceeds not from a particular quality of the agent, but from its ſubſtantial form, is to take an eaſy way to ſolve all difficulties in general, without rightly reſolving any one in particular; and would make a rare philoſophy, if it were as ſatisfactory as it is eaſy. If it be demanded, why jet attracts ſtraws, rhubarb purges choler, ſnow dazles the eyes rather than graſs, &c. to anſwer, that theſe, and the like effects, are performed by the ſubſtantial forms of the reſpective bodies, is, at beſt, but to ſay, what is the agent, not how the effect is wrought; and ſeems to be ſuch a kind of general anſwer, as leaves the enquirer as much at a loſs for the cauſes and manner of particulars, as men commonly are for the particular cauſes of the ſeveral ſtrange things performed by witchcraft, when told, that ſome devil does them.

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In ſhort, the form of a natural body, being, according to us, but an eſſential modification, and, as it were, the ſtamp of its matter, or ſuch a convention of the magnitude, ſhape, motion, or reſt, ſituation, and contexture, of the ſmall parts that compoſe it, as is neceſſary to conſtitute, and denominate it a particular body; and all theſe accidents being producible in matter by local motion; we may well ſay, that the firſt and univerſal, tho' not immediate cauſe of forms, is no other than God, who put matter into motion, eſtabliſhed its laws among bodies, and alſo, guided it in ſeveral caſes, at the beginning of things; and, that among ſecond cauſes, the grand efficient of forms, is local motion: which, by variouſly dividing, ſequeſtring, tranſpoſing, and connecting the parts of matter, produces in them thoſe accidents and qualities, upon account whereof, the portion of matter they diverſify, belongs to a determinate ſpecies of natural bodies: yet this is not ſo to be underſtood, as if motion were only an efficient cauſe in the generation of bodies; for 'tis alſo frequently one of the chief accidents, as in water, fire, *&c.* that concur to make up the form*.

SECT. III.

The doctrine of ſubordinate forms examin'd.

SOME late writers, as particularly *Sennertus*, teach that, beſides the ſpecific form in plants and animals, there reſide, and eſpecially in ſome determinate parts of them, certain other forms, proper to thoſe parts, but ſo ſubjected to the predominant form, as to deſerve the title of ſubordinate, being, during the reign of the ſpecific form, ſubſervient to it; tho' when the ſpecific form comes to be aboliſhed, theſe ſubordinate forms may ſet up

* This doctrine cannot be better illuſtrated, confirm'd, and improv'd, than by the words of that incomparable philoſopher Sir *Iſaac Newton*. "The *vis inertiæ*," ſays he, "is "a paſſive principle, by which bodies perſiſt "in their motion, or reſt; receive motion in "proportion to the force impreſſing it, and "reſiſt as much as they are reſiſted. By this "principle alone, there never could have been "any motion in the world. Some other "principle was neceſſary for putting bodies "into motion: for, from the various compoſition of two motions, 'tis very certain that "there is not always the ſame quantity of "motion in the world." . . . . . "But by reaſon of the tenacity of fluids, the "attrition of their parts, and the weakneſs of "elaſticity in ſolids, motion is much more "apt to be loſt than got, and is always upon "the decay." . . . . . "There "is therefore a neceſſity of conſerving and recruiting it by active principles, ſuch as are "the cauſe of gravity, by which the planets "and comets keep their motions in their orbs, "and bodies acquire great motion in falling; "and the cauſe of fermentation, by which the "heart and blood of animals are kept in perpetual motion and heat; the inward parts "of the earth are conſtantly warm'd, and, in "ſome places, grow very hot; bodies burn "and ſhine; mountains take fire; the caverns "of the earth are blown up; and the ſun continues violently hot and lucid, and warms "all things by its light. For we meet with "very little motion in the world beſides what "is owing to theſe active principles. And, "if it were not for theſe principles, the bodies "of the earth, planets, comets, ſun, and all "things in them, would grow cold, and "freeze, and become inactive maſſes; and all "putrefaction, generation, vegetation, and "life, would ceaſe; and the planets and comets would not remain in their orbs." *Newton. Optic.* p. 372—375.

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PHYSICS. for themſelves; and, in reference to thoſe parts of matter they belong to, exerciſe the functions of ſpecific forms: as in a dog or a horſe, beſides the ſenſitive ſoul, which is the ſpecific form of the whole creature, the fleſh, blood, and bones have their diſtinct forms appertaining to them, tho' they are ruled and employed by the ſoul, but as the matter which ſhe animates and informs: and, when by death, the ſenſitive ſoul or ſpecific form is depoſed or aboliſhed, the body is not preſently reſolved into the four elements, but thoſe ſubordinate forms ſtill preſerve the fleſh in the ſtate of fleſh, and the bone in the ſtate of bone; the one for a little, and the other for a much longer time. And this doctrine is urged from the ſpecific virtues obſervable in gathered plants; as the purgative faculty of rhubarb, ſena, and other cathartic vegetables, when they are deprived of the life they enjoy'd as plants. But it were not difficult to propoſe experiments, which would determine this matter otherwiſe, were it important enough to deſerve it. However, this doctrine of ſubordinate forms affords ſuch countenance to that of ſubſtantial ones, that the nature of our preſent diſcourſe forbids us to leave it untouch'd; tho' I ſhall not pretend to give a full and ſatisfactory account of ſo perplexed and abſtruſe a matter; it may be ſufficient, if I at preſent ſhew, that ſubordinate forms are explicable upon other principles.

And, 1. The name form, is a technical word, and not ſo well defined as were to be wiſhed. But without injury to the more uſual notion of it, we may obſerve that it is commonly ſome one, or a few conſiderable things, or conſpicuous phenomenon exhibited, or ſome peculiar operation performed by it, or ſome particular uſe, to which it is applicable, upon account whereof a form is attributed to a particular natural body; and only upon the receſs or abolition hereof, it is ſaid to loſe its form, or denomination. 2. The bodies, ſuppoſed endowed with ſubordinate forms, are, generally, either of the vegetable or animal kind; and, conſequently, being of a very compound nature, conſiſt of parts not all of the ſame ſpecies: this is evident in bones, which tho' entitled ſimilar parts, by diſtillation afford ſalt, oil, phlegm, ſpirit, and aſhes. And vitriol, tho' ſimilar as to ſenſe, may be artificially produced, by uniting the metalline particles of iron or copper, with the ſaline corpuſcles of diſtill'd ſalt or nitre. This inſtance I chuſe the rather, becauſe the patrons of ſubordinate forms ſeem, by them, to account for what happens in vegetables and animals, when the ultimate form is aboliſhed or expelled: tho' I ſee not, why we may not alſo attribute ſubordinate forms to ſeveral inanimate bodies. To illuſtrate this matter, let us borrow an example from rhubarb, the purgative faculty whereof is affirmed to proceed from a ſubſtantial form; which virtue, whilſt the rhubarb grew in the ground, proceeded, as they teach us, from the ſpecific form. Now if from the ſame rhubarb, we, by a convenient menſtruum, extract, together with the finer parts of the body, all the purgative virtue, (which may eaſily be done) why may not the remaining rhubarb, which will retain ſeveral of its former qualities, have a peculiar form, diſtinct from that which the ſchools call, *forma miſtionis*, to which thoſe qualities may be

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be attributed, and which, consequently, may be look'd upon as a subordinate form, with regard to that, which the entire, tho' inanimate rhubarb had before. PHYSICS.

An olive, or almond, when gathered, ceases to be animated by the vegetative soul of the tree, yet, on account of its subordinate form, retains the same shape, colour, &c. as before, by virtue of which form, it may be preserved sound for a whole year, or, perhaps, much longer so: so, by crushing the pulp of the olive, an oil may be squeezed out, endowed with noble qualities, and capable of preserving itself for several years. Now, I see not, why the form of this oil, from whence its qualities flow, may not be looked upon, as having been, whilst the liquor made a part of the olive, a subordinate form to that of the entire fruit. But to make this out by clearer examples; nature, in sulphur vive, has united under one form, two bodies of very different kinds, the one readily inflammable, and the other a great resister of fire; yet these two are easily separable, as appears by burning sulphur under a glass-bell. Again, in fossil cinnabar, under the form of a mineral stone, nature has ranged three, if not more, complete bodies, which have, each of them, its own distinct form, and that exceeding different from the others; as appears when these bodies are skilfully separated: from thence may be obtain'd a running mercury, an inflammable sulphur, and a concrete, whose properties we are not so well acquainted with. Now, if it be said, that these forms are not subordinate, but co-ordinate, it lies upon the objectors to prove it, who, perhaps, will find it no easy matter to shew, that the same ingredient, sulphur, for instance, is not as much subjugated by the form of the entire body, as that of the purgative portion of rhubarb, by the form of that drug. 3. All the different bodies, whereof, as parts, or ingredients, a compound is made up, are, by virtue of the composition and peculiar fabric thereof, so put together, that they concur to those actions or operations, which being proper to the body, are therefore presumed to flow immediately from the form of it. For instance, in gun-powder, three ingredients, upon a very slight mixture, produce, by a concurrent action, those wonderful effects, that are scarce to be match'd in nature; and which really result from the proportion of the ingredients, and the manner of their mixture. 4. Tho' the several parts, whereof the compound consists, do, in the proper actions of that body, jointly concur to perform them, yet these thus conspiring bodies, may, each of them, retain those properties which made it a distinct natural body before it came to be associated with the others, wherewith it makes up a more compound body.

5. And here it may be proper to observe, that the more considerate schoolmen, teach what very well agrees with the doctrine of subordinate forms. For when, in the generation of man, they tell us, that the *embryo* lives the life of a plant, and of an animal, before he attains to live the life of a man, it is plain, that, upon the introduction of the rational soul, the vegetative and sensitive souls, that before successively inform'd the *embryo*, do so no more; the additional human soul now becoming the true form of the human body. And these pre-existent souls are not abolished, and lose their being, but only their office, which, at first, was to inform the body of the *embryo*,

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PHYSICS. and now ceaſeth; ſo that they are not deſtroy'd, but only laid aſide. And this conſideration ſeems to admit, in many natural bodies, forms, that diſpoſe the matter they modify, for the reception of a nobler ſtamp, and may, therefore, be call'd preparatory forms, to diſtinguiſh them from thoſe more noted forms, which the ſchools uſually term ſpecific; as in the *embryo*, the vegetative and the ſenſitive ſoul, is but preparatory to the rational, which, alone, is ſaid to be the ſpecific form of man. But here I would not be thought to adopt all thoſe opinions, upon which I think it allowable to argue againſt ſuch as own them. For I take the difference between animating and natural forms to be ſo wide, that there is no juſt arguing in phyſical matters from one to the other. But whether in living creatures, the ſoul be always the true form, to all the intents and purpoſes the vulgar philoſophers would have it, I ſhall not here determine; nor whether, upon the ſupervention of an ultimate or ſpecific form, the forms, which thereby become ſubordinate, make but a part of the matter informed by the new one. They may, indeed, qualify the ſeveral portions of matter whereto they belong, to be fitter ſubjects or receptacles for the ultimate form; and there may be a neceſſity for ſuch previous diſpoſitions in the ſubject, becauſe the compound body is of ſuch a nature, that no other bodies, but what are peculiarly qualified, have a fitneſs to compoſe it. But it ſeems hard to conceive, how a ſubſtance diſtinct from matter, can properly be ſaid to have its capacity confounded with that of matter. And, notwithſtanding the diſtinction betwixt ſpecific and preparatory forms, the latter ſeem as true forms, whilſt they are predominant, as the ſpecific themſelves. For bodies are what they are, by the matter and modification which, for the preſent, conſtitute them, whatever they may afterwards prove: and it is not eſſential to the form, ſaid to be previous, that it is to be ſucceeded by another, ſaid to be more noble. A ſpring of ſteel, is a true and perfect ſpring, before it is made a part of a watch; and, by becoming ſo, it is not really bettered in its nature, tho' it be thereby made more uſeful to man.

6. It will not be amiſs to make ſome diſtinction between ſubordinate forms; there being one ſort of them, which may deſerve a peculiar name. For in men, horſes, ſheep, and other perfect animals, there are ſeveral parts, eſpecially thoſe that phyſicians call ſimilar, in oppoſition to organical ones, ſuch as bones, ligaments, membranes, which ſeem evidently to challenge peculiar and diſtinct forms: for the diverſity of their nature being very manifeſt, often perſevering a great while after death; thoſe, who allow a natural body to be what it is upon account of its form, cannot well deny diſtinct forms to theſe ſo diſtinct bodies; which, becauſe the bodies they conſtitute, are the parts of a human body, ſome ſchool-men have called partial forms.

7. Among the conſtituent parts of an animal or plant, there may lurk ſome ſeminal principles, or rudiments, that is, ſmall parcels of matter of ſuch a texture, that, tho' whilſt they remain aſſociated with the other parts of the compound body, they are not, by ſenſe, diſtinguiſhable from the reſt; yet, when it comes to have its predominant form aboliſhed, theſe ſeminal prin-

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principles or rudiments being ſet at liberty, and aſſiſted by external heat, and the ſoftneſs which uſually attends corrupting bodies, and, perhaps, by a lucky concourſe of other circumſtances, may fall to act according to their own nature, and generate inſects, moſs, *&c.* PHYSICS.

8. We may add, that when the ſpecific form of a body is deſtroy'd, the change is not often ſo great, as vulgar philoſophers imagine. The corruption of an animal, or other body, ought not to be looked upon, as happening in an empty ſpace beyond the univerſe, but in our ſyſtem, where being deprived of its ſpecific form, 'tis ſubject to be acted upon by the ſun, the air, and many powerful agents; by whoſe various concourſe with, and operations upon it, either the late pre-exiſtent forms may be aſſiſted to ſet up for themſelves, or new forms reſult from new aſſociations and contextures of the particles, which compoſed the body, now deſtitute of its principal, or ſovereign form.

Thus much being premiſed, let us try whether the corpuſcular philoſophy, according to which we have hitherto diſcourſed of forms, will not ſolve the phenomena, mention'd by *Sennertus*, better than his hypotheſis. I allow him to have rightly aſſerted, that in a plant or animal, there is ſomething beſides the bare *materia prima*, and the vegetative or ſenſitive ſoul, with its eſſential faculties. And that in ſome parts of ſuch bodies, there may lurk peculiar forms, which, when the life of the plant or animal determines, come to diſcloſe themſelves, ſeems probable, from the inſtances of the ſpecific virtue, ſurviving in gather'd plants. It is probable too, what *Sennertus* teaches, that this purging property in rhubarb, ſena, *&c.* as it does not flow from the vital ſoul of the plant, which is already deſtroy'd; ſo it does not proceed barely from the form of a mere mixed body: for it is no way likely, that ſo great a variety of ſpecific properties, wherewith roots plucked out of the ground, and fruits torn from the tree, are endowed, ſhould proceed merely from that general form, which belongs, in common, to compound bodies, as ſuch. But tho' there are ſome parts of this doctrine of ſubordinate forms, wherein I diſſent not; yet, there are others, wherewith I muſt confeſs myſelf unſatisfied. We are taught, indeed, that the ſpecific form of a body commands all the the ſubordinate forms; but I do not readily conceive, which way this dominion, attributed to the ſpecific form, is exerciſed; nor ſee any neceſſity of admitting ſuch a power in that form; or that the portions of matter, endowed with thoſe forms, ſaid to be ſubordinate, can, being under the degrees of ſouls, and, conſequently, unfurniſhed with knowledge and will, ſhew this preſumed ſuperintendent form any other obedience, than ſuch as the parts of a clock or engine may be ſaid to yield to one another. I ſhould, therefore, rather conceive, that when ſeveral bodies of differing natures are aſſociated, to compoſe a body of one denomination, tho' each of them be ſuppoſed to act according to its own peculiar nature; yet, by reaſon of the coaptation of the parts, and the contrivance of the compound body, it muſt often happen, that the action, or effect produced, will be of a mixed nature, and different from that, which ſeveral of the parts, conſider'd as diſtinct bodies, or agents, tended to, or would have performed.

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PHYSICS. formed. Thus, in a balance, by putting a weight into one of the ſcales, the oppoſite, tho', as a heavy body, it has a natural tendency downwards, will, by virtue of the fabric of the inſtrument, mount upwards. So that thoſe actions, which *Sennertus*, and others, attribute to the conſpiring of ſubordinate forms, to aſſiſt the ſpecific and preſiding form, we take to be but the reſulting actions of ſeveral bodies, which, aſſociated together, are thereby reduced, in many caſes, to act jointly, mutually modifying each others actions; and that which they aſcribe to the dominion of the ſpecific form, I attribute to the ſtructure, and eſpecially to the connection of the parts of the compound body. Thus, in a clock, tho' all the parts whereof it conſiſts, contribute to the performance of the things belonging to a clock, as regularly as if they intended to do ſo, and did not only concur, but knowingly conſpire thereto; yet, in all this there is no ſubſtantial form to ſuperintend their motion, but the weight tends downwards, as uſual; and the hand, wheels, and other parts, only perform ſuch motions, as they are forcibly put into by thoſe bodies, which, by the deſcending weight, are themſelves ſet in motion. And, even the prodigious effects of gun-powder, are owing to the mechanical texture, and that ſlight and eaſy way, wherein the ingredients are mixed; which are alſo with eaſe diſſociated, by a chymical proceſs.

But to illuſtrate reſulting actions by an inſtance purely phyſical; by taking two powders, fit for my purpoſe, one blue and the other yellow, and mixing them in a certain proportion, the mixture exhibited a green colour, which did not flow from any new predominant form, making the blue and yellow corpuſcles ſubſervient to its purpoſes; but only, from the mixture of thoſe bodies, the diſtinct actions of the blue and the yellow corpuſcles made upon the eye a compound impreſſion, like that of bodies, whereto their ſpecific forms are ſuppoſed to impart, among other qualities, greenneſs. Thus alſo, when vitriol, and ſublimate, are made by art, there needs nothing, beſides the manner, wherein the ſaline, and metalline particles are contexed, either to hold the parts together, and keep them united into one body, or to enable the mixture to effect ſeveral things, which neither of them would have performed apart. And, as in a watch, the ſpring is really a ſpring, and acts as one, whilſt it is a part of the watch, tho' by reaſon of its connexion with the other parts, it is reduced to concur, with thoſe, towards exhibiting the phenomena proper to the whole engine; ſo, in many compound bodies, beſides the ſpecific form, which the body has, as ſuch, and which may be called its total or general form, the particular bodies, (by whoſe aſſociation and conjunction it is made up) may enjoy their own diſtinct forms, and be therefore called partial forms: and theſe bodies, tho' they are part of the whole, whilſt it ſubſiſts, and, by their connexion with the reſt, concur to the operations of the body, as ſuch, (which joint operations are uſually attributed to the ſpecific form) yet they do not always ſo depend thereon, but after it is aboliſhed, they may retain their own nature; as a bone, will be a bone for whole ages after the animal it belonged to is dead. Whence we need not wonder, that ſeveral forms ſhould ſurvive

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in bodies deprived of their ſpecific form. For, indeed, thoſe which are called ſubordinate, may, as was before obſerved, be as true and real forms, as thoſe which bear the title of ſpecific; and even, whilſt theſe are in being, there are many things which compound bodies perform by virtue of their particular forms, rather than of the ſpecific. Thus in gun-powder, the blackneſs proceeds not from the compoſition, but the coals; and the nitrous taſte from the ſalt-petre. PHYSICS.

If we conſider the arbitrary uſe of the word form, we ſhall find, that thoſe things, upon account whereof we attribute a particular form to a natural body, are but very few of the many attributes which belong to it. Now the form of a body being really no more than a convention of attributes, whereby the matter is ſtamped, and denominated; it is very probable, that hoſtile cauſes may often deprive the matter of thoſe accidents, which conſtituted the ſpecific form, and yet leave the reſt, which, according to the law of nature, ought to continue there, till ſome competent agent put the body out of that ſtate, wherein, upon the form's deceaſe, it was left. To clear up this matter, we muſt conſider, that the ſame body may have two kinds of modification, and be thereby fitted for two, if not more, ſtates and kinds of operations, not neceſſarily dependent upon each other. For, as the ſpring of a watch is, by virtue of one part of its texture, an elaſtic body, and, upon account of another, iron; and, therefore, tho' being caſt red-hot into cold water, it will become ſtiff and brittle, and, conſequently, ceaſe to be a ſpring; yet it will ſtill continue iron, with all its peculiar attributes. Thus in a roſe, we may diſtinguiſh two modifications of the matter; one, whereby it is fitted to receive, from the buſh it grows on, a certain peculiar and ſpirituous ſap, by whoſe intervention and concurrence, it has nouriſhment and growth, and, conſequently, exerciſes vital functions, as a part of a living plant; and another, which conſiſts rather in the texture of the more ſtable parts: and this texture being commonly more permanent and durable, than the other part of the modification, wherein the life, participated by the roſe, conſiſted, may laſt, when the flower is deprived of its ſoul and ſpecific form, by removal from the buſh, and retain thoſe qualities, that naturally reſult from a parcel of matter ſo contrived. And, as a mill is capable of performing ſeveral things, only when the water, that paſſes through certain parts of it, puts them, and, by their means, others, into motion; ſo there are many things not performable by a plant, unleſs watered with a vital liquor. And, as a mill may, nevertheleſs, retain the nature of a ſtructure, uſeful for other purpoſes, tho' the drought of ſummer have, perchance, depriv'd it of its water, or the froſt congeal'd it into ice; ſo, tho' the ſoul of a plant be deſtroy'd, or ceaſe to act, the body may, upon account of the more permanent ſtructure of its ſtable parts, retain a fitneſs for many of the ſame purpoſes whereto it ſerved before. This compariſon, perhaps, will not hold in all circumſtances: however, there are ſeveral inſtances of vegetables reſuming the faculty of growing, long after they have been thought lifeleſs; as the roſe of *Jericho*, the aloes-plant, *&c.* And even ſome animals are not ſo very unlike theſe plants, as one would imagine: for flies, waſps, *&c.* will per-

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PHYSICS. perform their usual actions, upon the application of fresh warmth, some time after they have seem'd to be dead.

To proceed, it may be observed, that even in a body, which hath lost its specific form, the remaining qualities do not always flow from the form of the entire body; but from the peculiar form of some particular parts of it, which being separated therefrom, tho', perhaps the more stable parts that remain, will keep the visible structure from being manifestly altered; yet this remaining body shall be quite deprived of its noble properties; as may appear from making the extract of rhubarb, wherein its whole purgative virtue resides; and from some preparations of cinnamon, and other substances of fine parts, which, upon the loss of them, remain but the carcasses of what they were. And, besides this pre-existent and surviving modification, it is often very possible, that new qualities and properties may be discloséd upon the abolition of the specific form, tho' they were not actually in any part of the matter, but are produced in it by a concurrence of the texture and dispositions left there by the late form, and the operation of external agents. As, when out of the flesh of a dead animal, musk or insects are generated; or, as when a lime-stone calcined, and left in the open air, in time affords true and inflammable salt-petre. But as to the two modifications of living creatures before-mention'd, I fear we sometimes attribute to the specific form, things, that may be well perform'd without it, by the more stable modification of the body, assisted by an easy concourse of natural agents. Thus, tho' the exclusion of excrements be unanimously ascribed to the soul, which, for that purpose, is said to be endowed with a peculiar faculty, call'd expulsive; yet, the excrements have been often discharged, long after the creatures were unquestionably dead. And tho' the maturation of fruit be a great alteration, supposed to be wrought by the vegetative soul of the plant; yet it has been observed, that apples, grapes, *&c.* gathered before they were ripe, and laid on heaps together, will ripen well enough afterwards: and the common histories abundantly prove the same in other the like productions. I might add, that even in our cold climate, onions, and some other bulbous plants, will, in the spring-time, shoot out of their own accord. And, even in animals, some things, confidently presumed to be the proper effects of the soul, may be really performed by the texture of the body, and the ordinary and regular concourse of external causes; as the growth of nails, hair, *&c.* after death, which continues not only whilst the impressions left by the soul upon the carcass, are yet vivid and recent, but for a much longer time than hath been imagined; a memorable instance of which is given by *Paræus*, who, speaking of a body, which he, by embalming, preserved for more than twenty five years, affirms, "that it still "remained whole and sound; and as to the nails, having often pared "them, he always observed them to grow again to their former length."

The patrons of *Sennertus*'s opinion, look upon it as a cogent argument to prove, that the soul performs almost all that is done in the body, because in the corps of a man newly dead, tho' the organization remain the same, yet the animal and vital functions perfectly cease. But tho' the visible fabric

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may continue, for a while, without any manifeſt alteration; yet, who can PHYSICS. aſſure us, that the internal organization is not conſiderably changed and vitiated? The body of an animal conſiſts not only of ſolid and ſtable parts, as bones, muſcles, *&c.* but of ſeveral ſoft ones, as the brain, nerves, *&c.* and of ſome that are fluid, as the blood, and other juices; and, which is, in our caſe, very conſiderable, requires a convenient combination of all theſe: whence it follows, that the external frame of the body remaining unaltered, yet, upon death, there may be great alterations in the texture of the blood and humours, and in the ſtructure of other internal parts. And theſe changes may quite ſpoil the organization of the body, and render it unfit to perform the uſual functions of ſuch an engine. But ſome of the things hitherto delivered, may be diſputed for want of aſcertaining the meaning of the word, life; which is indifferently apply'd to minerals, plants, animals, and ſpirits: and it is very difficult to avoid miſtakes, or unprofitable diſputes, if men do not uſe words in the ſame ſignification. It may, therefore, be convenient to diſmiſs ſo much of the controverſy, as, on this account, is liable to ambiguity, and apply the chief points of our doctrine of ſubordinate forms to inanimate bodies. And here, for order's ſake, I ſhall caſt the principal things into diſtinct propoſitions, and annex a ſhort comment to each.

1. *The word form has a very indeterminate ſignification.* This we have already ſhewn; and the perſons, who uſe it, do not yet pretend to have agreed, how many, or what things, are ſufficient to entitle a portion of matter to a determinate and diſtinct form. For there are many bodies, ſuch as treacle, beer, gun-powder, coal, ink, *&c.* about which, men ſeem not to have conſider'd, whether they ought to have particular forms aſſign'd them; and there are others, about which the *Peripatetics* diſpute, whether they ſhould have particular forms allow'd, or no. Ice is, by ſome, made to be a diſtinct kind of body, whilſt others will have it to be only water altered, and thereby deprived of its fluidity, not its form. Nay, even about the elements themſelves, the ſchool-men fiercely diſpute; a whole party denying them to have any other forms, than the firſt qualities, by which they are uſually diſtinguiſhed. And, ſome bodies, variouſly conſider'd, ſeem to have a title to more than one form: for inſtance, it is difficult to determine, whether pure lead, made into a body, like *Vitrum ſaturni*, is moſt properly a metal, or glaſs. The like difficulty occurs, when miſletoe grows very large on a hazle, or when an apricock or a peach is inoculated, and proſpers upon the bough of a plumb-tree; and when red or blue amel is made of calcined tin, which they call putty, and of the ſalt and ſand, whereof the glaſsmen make what they call their fritta, and of ſome burnt copper, or other metalline pigment; examples, with others of the like kind, which might, perhaps, ſomewhat perplex the ſchool-men to accommodate fairly to the vulgar doctrine of forms, at the introduction whereof, probably ſuch inſtances were never thought of.

2. *It is difficult to decide the nobleneſs of forms.* This point, alſo, has been partly handled already; and, indeed, as nobleneſs is rather a civil or political, than a phyſical qualification, it is often hard to determine, which, of two

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PHYSICS. two forms, is the moſt noble. To ſome examples already given of this difficulty, beſides the late inſtance in glaſs of lead, may be added that of antimony made *per ſe*; crude antimony being fitter for ſeveral purpoſes, both mechanical and medical, than the vitrified calx; and this, again, being fitter for other uſes, than that, which has not been freed from its more fugitive parts. It was a diſpute among the antients, whether their *Electrum*, a compoſition of gold and ſilver, was nobler than either of thoſe metals: and when chymiſts have made a precipitate of gold and mercury, it is queſtionable, whether that be a nobler thing, than the gold alone; tho' if a chymical phyſician were judge, he would give it for the gold improved by the change; tho' a goldſmith would conclude it debaſed by the alloy, and, by melting it with borax, free it from the quick-ſilver, and reſtore it to its priſtine form. It might, alſo, be diſputed whether, tho' in living creatures the ultimate form be more noble than its previous harbinger; it may not be ſometimes otherwiſe in bodies inanimate, as well as in the productions of art. When an artificer makes ſilver ſolder, by adding to the ſilver a certain proportion of braſs or copper, tho' he thereby obtains an uſeful mixture, yet it may be much queſtion'd, whether this brittle ſubſtance be not leſs noble, than the ſilver alone. And when a plant, growing by ſome petrifying ſpring, is, by imbibing that water, turned, at length, into a ſtone, tho' the rarity of ſuch things makes men prize them; yet it may well be queſtioned, whether the new form be not leſs noble, than that which the plant had before.

3. *In many bodies, the form is attributed upon the account of ſome one eminent property, which, if it be preſent, and continue, tho' many other things ſupervene, or are wanting, the matter is ſtill looked upon as retaining its form, and therefore allowed its uſual denomination.* An example of this, we are furniſhed with, by the late inſtance of *vitrum antimonii*; for tho' in many reſpects, it puts on the appearance of glaſs, yet it retains ſo much of the antimonial nature and properties, as to be vomitive and purgative, as well as *crocus metallorum*. The expreſſed oils of olives, almonds, and other unctuous vegetables, differ much from thoſe fine eſſential oils, drawn by diſtillation; and both of them from thoſe empyreumatical ones diſtilled in retorts by violent fires; yet all theſe very different liquors are reckoned among oils, becauſe they agree in being fluid bodies, unctuous to the touch, and ſuch as will not mix with water. So, altho' ſome ſalts are very fugitive, as thoſe of harts-horn, urine, *&c.* others very fixed, as that drawn from the calx of tartar, or the aſhes of wormwood, *&c.* yet all theſe are numbred among ſalts, becauſe they agree in the reſpects for which we allow bodies that denomination. And, indeed, by reaſon of the unſettled notion of the word form, and its uncertain application to conſtitute diſtinct claſſes or kinds of bodies, I have doubted, whether ſeveral forms be more than metaphyſical conceptions; by virtue of which, bodies, very different in nature, are comprized in the ſame denomination, becauſe they agree in a fitneſs for ſome uſe, or in ſome other thing that is common to them all, rather than in ſuch true phyſical forms, as make bodies of the ſame denomination, likewiſe of the ſame ſpecific nature. However, theſe forms

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forms ſeem to be very general things, and more ſo, than is commonly obſerved. And I have alſo queſtioned, whether ſome of thoſe things, upon account whereof men rank bodies in a particular ſpecies or claſſis, be ſo properly the true and intrinſic forms of thoſe bodies, as certain ſtates of matter, wherein bodies, very differing in nature, may agree; as water, wine, and many other different liquors, may, each apart, be made, by congelation, to paſs into that ſort of body we call ice: and not only the ſuet and fat of animals, and the expreſſed oils and ſpirits of fermented vegetables, but alſo ſeveral mineral, and metalline concretes, may be made to paſs into that claſs of body we call flame. PHYSICS.

4. *By reaſon of the conjunction or connexion of the parts that make up a whole, ſeveral things will often be performed by the concurrent action of theſe united parts.* Such operations are of kin to thoſe, which the ſchoolmen call *actiones communes*; as when a bullet is let fall upon a pavement, tho' it touches the body it falls upon, but in a very ſmall part of its ſuperficies, yet the plane receives the action of the gravity of the whole body; thoſe parts that do not immediately touch it, ſtriking it by the intervention of thoſe which do. So, likewiſe, in a boat, the limbs and clothes of a man, who ſtands upon the deck, and all the parts of a watch, if he carries one in his pocket, jointly gravitate on the veſſel, tho' only the ſoles of his feet, or ſhoes, immediately preſs upon it; and the wheels and other parts of the watch may be moving, at the ſame time, very different ways. Now, in organical bodies, and ſeveral others, both natural and factitious, thoſe things which are performed by the parts, as in a ſtate of conjunction, are often aſcribed to the form; as in a watch, moſt of the principal phenomena ſo depend upon the concurrent action of the ſeveral parts, that few of them can be out of order, but they will hinder thoſe phenomena from appearing at all, or, at leaſt, from being well and regularly produced.

5. *We may yet, in a due ſenſe, admit, that in ſome bodies, there are ſubordinate forms.* I know it is pretended, that one body can have only one form: but tho' a body can have only one total and adequate form, yet, its parts may have their partial forms ſubordinate to that; as the ſteel-ſpring, and braſs-wheels, of a watch, may retain their diſtinct metalline forms, tho' the watch they compoſe be but one. And the ſchoolmen themſelves, with many of the antients, have aſſerted, that in compound bodies, the elements retain their reſpective forms, notwithſtanding the new form, that belongs to the mixed body. It is alſo objected, againſt the ſupervention of a higher form, that a body, being already complete in its own kind, by its own form, no other form can accrue to it, without making what is called *ens per accidens*. To this I anſwer, that the notion of an *ens per accidens* belongs rather to metaphyſics, than natural philoſophy; and in what its eſſence conſiſts, is ſtill ſo hotly diſputed, that no arguments from it, can juſtly affect the preſent caſe: and, indeed, when we conſider, that the ſchools allow the ſoul and body to make up a man, who, according to them, is *unum per ſe*, and not *per accidens*; and teach, that the rational ſoul, which is a ſubſtance, and the underſtanding and will, which are ſaid to be its faculties,

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PHYSICS. culties, and so its accidents, make *unum per se*; by a parity of reason, that predicate or qualification, may well be taken in as large a sense as is requisite for our purpose. So that if the parts of a body, whether natural or factitious, be, by their union, brought to become the principle of a property or operation, which belongs to neither of them single, I see not why such a body may not pass for *unum per se*, as well as several bodies which pass under that notion. It may be farther answered, that tho' a body, by its own form, be complete in its kind, yet it may be capable of advancement to a nobler state by an accession, that shall not ruin its former nature, but enable it to co-operate to nobler actions, than its former could reach. Thus when a spring is made part of a watch, it thereby, without losing the nature of a spring, contributes to the noblest phenomena of so curious an engine: and the ingredients of gun-powder, by the superinduction of the form, or new contexture they acquire by mixture, are, each of them, enabled to co-operate to the performance of things, far exceeding the utmost they could do before. Nor will it follow from this superinduction of forms, that there may be a form of a form, as well as of matter; but only that to a body, which hath already a form, a farther form may supervene.

6. *The supervention of a new form is often but accidental to the pre-existent form; and does not at all destroy its nature, but modify its operations.* A needle, not touched by a load-stone, has its own form, as a piece of steel, as well as the figure of a needle; but, when it comes to be excited by the load-stone, there are then new and wonderful properties superinduced; and this needle is then able to point regularly north and south, attract other needles, and communicate a verticity to them; and so is fit for much nobler uses, than before. And this new modification so regulates its motions, that, tho' before it was indifferent, if nicely poised, to rest at any point of the compass; it is now determined to keep moving, 'till it points north and south, and to rest in that position only: yet, by drawing this magnetic needle, after a certain manner, upon the pole of a vigorous load-stone, you may, in a moment, deprive it of all its additional faculties, tho' it will remain as true a steel-needle as at first. And a little reflection on the forementioned instance of the spring of a watch, will shew what it is, that the structure or modification, whence the form of the whole, according to us, results, does to a body already endowed with its own form. For, as the spring, tho' it retain its own nature, and acts according to it; yet, by the contrivance of the watch, it is not only so pent in, that it cannot gain its full extent, as otherwise it would, but by the same contrivance, its incessant endeavour, to stretch itself, is so moderated and managed by the wheels and balance, that it principally concurs to set all the other parts in motion, and to perform the office of a watch: so in natural bodies, what is performed by the supervention of a higher and total form, is, that by virtue of the connexion and structure of the parts introduced with this new form, the action of the particular parts, tho' they retain their own partial forms, and act, as far as they can, according to them, is so mastered, or otherwise modified, that they are brought to concur to those things that are done by the

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the whole body as one agent, and become ſubſervient to the operations, that PHYSICS. are proper to the body in its new and ultimate capacity. Thus when a piece of lead is, without addition, vitrified by the mere action of the fire; this happens to the body, upon its acquiring the form of glaſs, that, whereas, before, the metalline particles were ſo inconveniently ſituated, and ſhaped, that they denied paſſage to the rays of light; and, by reaſon of their contexture, compoſed a body that was very flexible; they become now ſo ranged, and otherwiſe altered, that they freely ſuffer the light to paſs them, but admit not of being freely bent as before. And when ſalt-petre, by the addition of a ſmall proportion of brimſtone and coal, is made into gunpowder; this happens to it, from its acquired modification, that if a little fire fall thereon, it will not, as before, leiſurely conſume, and leave behind it a conſiderable portion of the whole body, in the form of a fixed or alkalizate ſalt, but fly away all at once, and leave little or nothing behind it.

7. *Beſides the ſpecific actions of a body, that harbours ſubordinate forms, there may be ſeveral others, wherein ſome of the parts act according to their particular and priſtine nature.* This follows from what we lately ſhewed, that the total and ſpecific form has not ſuch a dominion over the partial and ſubordinate ones, as the patrons of theſe forms imagine. For tho' by virtue of the modification of the whole, the operations of the parts or ingredients are ſo guided, as to concur to thoſe operations that belong to the whole, and are requiſite to be performed by a joint-action; yet, in other reſpects, as it is not neceſſary, that ſuch bodies ſhould have their parts entirely under the dominion of the ultimate form, they may act according to their diſtinct and particular qualifications. But this will be farther cleared by ſhewing, that the ſame things may happen to ſeveral bodies, which appear in a watch, where, tho' the form of the engine, in many reſpects, makes the ſprings and wheels, and other parts, concur to perform the operations proper to ſuch an engine, yet the wheels may look bright and yellow, the ſpring may move a magnetic needle, and other parts may do other things, not by virtue of the form of a watch, but by virtue of their own qualities. Thus when in pills, and other medicines, made up of ſeveral ingredients, the compoſition has ſome reſulting virtues diſtinct from thoſe of the ingredients, and belonging to the compoſition; yet, it may often happen, that ſome particular ingredient will not only retain its former nature, but ſo retain it, that the compoſition is endowed with that quality, only upon account of that ingredient. Thus ambergreece, mixed with purgative ingredients, retains its own grateful ſmell, and communicates it to the whole maſs, whereof the pills are made: and moſt purging pills taſte ſtrong of the aloes, whatever the other ingredients be. A farther inſtance we may take from *Venice* treacle, not too ſtale: for tho' it be acknowledged, that opium works by a ſpecific quality; and tho' it be here blended with above threeſcore other ingredients, in far greater quantities; yet, in ſpite of the *forma compoſiti*, it retains its proper narcotic virtue; and, upon that account, renders the whole a powerful remedy in ſeveral diſtempers, where quieting medicines are proper. A no leſs evident example we have in the precipitate of gold and mercury: for tho'

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PHYSICS. by virtue of the union of the ingredients, the reſulting powder may gain ſeveral qualities, which neither the gold, not the quick-ſilver, had apart; yet, the ſalivating faculty of this precipitate, belongs to it barely on account of the mercurial ingredient.

8. *That which, in many bodies, is looked upon as the ſpecific form, is, often, only the moſt eminent.* We muſt here recollect, (1.) That the word form, has no ſettled ſignification; ſo that ſeveral bodies to which particular forms are aſſigned, deſerve not that privilege better than many others, wherein no peculiar and diſtinct form is conſider'd. (2.) That the forms of inanimate bodies are but reſpective things, reſulting from the co-exiſtence of particular corpuſcles or parts, after a determinate manner. (3.) That it is uſually from ſome particular reſpect, or fitneſs to ſome particular uſe, that men aſcribe this or that form to a particular body. (4.) That the nature and fabric of a body may manifeſtly fit it to anſwer more than one of thoſe reſpects, on whoſe ſcore bodies are denominated, or may be ſuited to more than one of thoſe uſes; an aptitude for which, when found ſingle in another body, is ſufficient to make it be referred to a diſtinct kind: as the *vitrum antimonii*, tho' conſider'd by ſome as glaſs, is, by a phyſician, looked upon as a medicine. (5.) That it is not neceſſary, theſe conjugations of qualities ſhould have a ſtrict dependence upon one another; as the emetic properties of the antimonial glaſs belong not to it as glaſs: nor is it neceſſary that, if this very portion of matter had not the form of glaſs, it would want or loſe theſe properties. (6.) That ſince the nobleneſs or ignobleneſs of forms depends on the greater or leſs uſe of the body; one man may, in the ſame body, look upon one kind of modification, and another upon a quite different one, as the higheſt form of that body. Thus a watch, that ſhews only the hours and their quarters, hung at a ſtring, and made to ſwing as a pendulum, would to an aſtronomer, who was to make nice obſervations, be moſt uſeful in the capacity of a pendulum; becauſe, as that, it may divide a minute into ſeconds, half ſeconds, *&c.* but for other men, who, tho' they want an inſtrument to meaſure time, require not ſuch minute ſubdiviſions of it; the little engine we ſpeak of, will be much more uſeful and conſiderable, in the capacity of a watch. (7.) Hence it may often happen in inanimate bodies, whether natural, or factitious, that the ultimate or chief form, is not the preſiding form, but only the moſt eminent; by which, I mean not ſimply the nobleſt, but that which is, for the time at leaſt, the moſt conſidered: or, in other words, the form moſt regarded, is not ſo much that which reigns, as that which denominates.

9. *Theſe forms ſeem to be rather concurrent, than ſubordinate.* For if a body can have ſeveral ſuch conjugations of accidents or modifications, as may entitle it, in differing reſpects, to different forms; and that form, which is conſidered as the moſt eminent, be not the preſiding form, nor ſo much as always the nobleſt; may not theſe forms, which co-exiſt in the ſame body, be more fitly termed concurrent or coincident, than ſubordinate? And, indeed, as to inanimate bodies, this dominion and ſubjection, which is imagined between forms, ſeems to me, in many caſes, neither well eſta-

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bliſhed, nor eaſy to be explained. I doubt too, that ſometimes we miſtake names for things; and becauſe, when a body, by the action of proper agents, obtains ſuch a modification as fits it for particular actions and uſes, we call it by a certain name, and attribute a form to it; we are apt to conclude, that the faculties and qualifications it enjoys, and the things it is able to do, are owing to this form, as if it were ſome diſtinct and operative ſubſtance, put into the body; and really began, guided, and over-ruled the motions and actions of the compoſition. Whereas, indeed, what we call the form, if it be not, ſometimes, little more than one of thoſe airy things, which the ſchools call an external denomination, ſeems often to be rather a metaphyſical conception, than a phyſical agent, that performs all things in the body it is aſcribed to. Thus when a piece of ſteel, conveniently ſhaped, is, by a due temper given it, turned into the ſpring of a watch; the motions of the watch, tho' proceeding from this ſpring, proceed not from the form of the iron; and the ſpringineſs itſelf, flows not immediately from that form, but from a mechanical and adventitious texture, ſuperinduced in the metal, and given it by ſeveral outward agents, as the fire, the hammer, *&c.* And it is ſo far from evident, that, in bodies inanimate and compounded, the moſt eminent, and moſt conſidered form, muſt have a dominion over, and an efficacy in all operations and actions of the compoſition, that even in bodies not ſo compounded, it is not always neceſſary, that the ſpecific form ſhould have ſo much as a concurrent ſhare in what is performed: for external agents may introduce ſuch qualities into the body we ſpeak of, as, being once there, will ſuffice for actions and productions, ſuitable to their own nature, whether the form be active in aſſiſting them or no. We ſee that boiling water, taken off the fire, will raiſe bliſters on a man's hand, and perform other things, which are uſually the effects of fire, only by virtue of the adventitious heat it has received; tho', according to the *Peripatetics*, the form of water, which is an element naturally cold, as well as moiſt, ought rather to oppoſe, than promote the action of the preternatural heat. And the like might be ſaid of a heated iron taken from the fire. It may, indeed, be pretended in favour of the ſchools, that it is the fire, which got into, and yet remains in the iron, that cauſed theſe effects. But this ſubterfuge would involve them in very perplexing difficulties. However, I will put a caſe where it cannot be made uſe of: ſuppoſe, then, the iron to be heated, not by the fire, but by forcible ſtrokes between a hammer and anvil, both of them actually cold. When a piece of ſilver is, by being hammer'd, or drawn into wire, made a ſpringy body, it will be able to perform many things by that acquired elaſticity, which do not at all flow from the form peculiar to the metal: for not only copper, ſteel, and many other bodies, may be made ſpringy too; but, if you heat it in the fire, the goldſmith will aſſure you, that it is as true and as good ſilver as before; and yet it will ceaſe to be a ſpring. And ſo when a ſmith makes a file, by forming many little channels on it, a-croſs one another, and, afterwards, hardening the ſteel; by virtue of this roughneſs, which is given it by external agents, it acquires a durable roughneſs, upon which account it is qualified to perform many.

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PHYSICS. many conſiderable things, whereto the form of the mere metal does not, for ought that appears, concur. And tho' hardneſs contributes to make a good file, yet, not only the iron was as true and perfect iron, before it became rough as afterwards; but even that degree of hardneſs, which qualifies our inſtrument to be a good file, flows not immediately from the form of the metal; for that was true iron when ſoft, and its eminent degree of hardneſs was given it by the temper it received from the ſmith.

But, to conclude, I muſt again complain, that the uncertain ſignification and uſe of the terms, employ'd about theſe points, are apt to occaſion much darkneſs and difficulty in our enquiries into the things themſelves; and, I am apt to think, that if the meaning of the terms, form, life, ſoul, animal, vegetative, and ſome few others, were clearly defined, and agreed on, a great part of the perplexing controverſies, about ſubordinate forms, with what relates to them, would appear to be diſputes about words only. And if I ſhould, any where in this diſcourſe, have dropt into a verbal controverſy myſelf, I can ſafely ſay, that my endeavours have all along been to expunge received errors, and to eſtabliſh a better theory of theſe matters.

SECT. IV.

The production, and reproduction, of forms.

WE have already ſeen, it is by a kind of tacit agreement, that men diſtinguiſh the ſpecies of bodies; and that thoſe diſtinctions are more arbitrary, than moſt are aware of: nor have I yet met with any genuine and ſufficient boundary for the ſpecies of things, or any determinate number of qualities, neceſſary to conſtitute diſtinct kinds of natural bodies. We, therefore, look upon thoſe as diſtinct ſpecies of bodies, that have had diſtinct names aſſign'd them; tho', perhaps, many of them differ much leſs from one another, than other bodies, eſteem'd but of one ſort. Whether water and ice ought to be eſteem'd diſtinct bodies, is ſo little evident, that ſome affirm, water loſes not its own nature, by being turned into ice; which is made plauſible, by the reducibleneſs of it back again into water: yet others again make them diſtinct ſpecies of bodies, becauſe the one is fluid, and the other ſolid; and, alſo, becauſe ice is, commonly, more or leſs opake, and lighter *in ſpecie*, than water. We may add, that ice, beaten with common ſalt, will freeze other bodies, when water, mixed with ſalt, will not. And I would be reſolved, whether muſt, wine, ſpirit of wine, vinegar, and tartar, are bodies ſpecifically diſtinct. The like queſtion might be asked of an egg, and the chick that is afterwards hatched out of it; as alſo, of the eggs of ſilk-worms, which are firſt ſmall caterpillars, then aurelia's, and next butter-flies. And whether the anſwer to theſe queries be affirmative or negative, I doubt, the reaſon that will be given for either, will not hold in ſeveral caſes. And it may ſtill be more puzzling to ask, whether a charcoal, throughly kindled, differs ſpecifically from another charcoal. Nor is it eaſy to determine, whether clouds, rain, hail, and ſnow, be all ſpecifically diſtinct from water, and from each other.

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But if ſuch ſlight differences diſcriminate theſe bodies, it will be hard to give a ſatisfactory reaſon, why other bodies, that differ in more conſiderable particulars, ſhould not enjoy the ſame privilege; as, I preſume, that ſnow differs leſs from rain, than paper from rags, or glaſs, made of wood-aſhes, from wood. And, indeed, men having, by tacit conſent, agreed to look upon paper, glaſs, ſoap, ſugar, braſs, ink, pewter, gun-powder, *&c.* as diſtinct ſorts of bodies; why may they not be thought to have done it on as good grounds as thoſe, upon which many other differing ſpecies of bodies have been conſtituted? It will not ſuffice to object, that theſe bodies are factitious; for it is the preſent nature of bodies, which ought to be conſider'd in referring them to ſpecies, which way ſoever they came by that nature: for ſalt, which, in many countries, is made by boiling ſea-water in proper veſſels, is as true ſea-ſalt, as that which is made in the iſle of *Man*, by the bare action of the ſun upon the ſea-water, left behind in hollow places, after a high ſpring-tide. And ſilk-works, hatch'd by the heat of a human body, and chickens produced in *Ægypt* by the heat of ovens or dunghills, are as true ſilk-worms and chickens, as thoſe which are hatched by the ſun or by hens. PHYSICS.

And whatever may be ſaid of factitious bodies, where man, by inſtruments, only gives figure to the ſenſible parts of matter, as when a ſtatuary makes an image; yet the caſe may differ in thoſe other factitious productions, wherein the inſenſible parts of matter are altered by natural agents, which perform the greateſt part of the work among themſelves, tho' the artificer be aſſiſtant in putting them together. And, therefore, all chymical productions may well be look'd upon as natural bodies; ſince the fire, which is here the grand agent, doth not, by being employ'd by the chymiſt, ceaſe to be a natural agent; ſince nature herſelf, by the help of the fire, ſometimes affords us the like productions, wherewith the chymiſt preſents us. Thus in *Ætna*, *Veſuvius*, and other burning mountains, ſtones are turned into lime, and ſometimes vitrified, whilſt aſhes, and metalline flowers of ſeveral kinds, are ſcattered about the neighbouring places; and plenty of flowers of ſulphur, ſublimed by the internal fire, appear about the vents, at which the fumes are diſcharged into the air. And many bodies we meet with in the lower parts of the earth, and think to have been formed there, ever ſince the beginning of things, may have been more lately produced, by means of ſubterranean fires. Thus lead may be turned into minium, and tin into putty, or ſeveral ſaline and ſulphureous corpuſcles, riſing in fumes, may alter the nature of other ſubterranean bodies; or, by convening among themſelves, conſtitute particular concretions; as the fumes of ſulphur and mercury unite into vermilion, which is ſo like to the mineral, whence we uſually obtain mercury, that they both go by the ſame name of cinnabar. Since then theſe productions, being of nature's own making, cannot be denied to be natural bodies; why ſhould the like productions of the fire be thought unworthy that name, only becauſe the fire, which made the former, was kindled by chance in a hill, and that which produced the latter, light up by a man in a furnace. And if flower

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PHYSICS. of ſulphur, lime, glaſs, and melted mixtures of metals and minerals, are to be reckoned among natural bodies; it ſeems but reaſonable, that, upon the ſame grounds, we ſhould admit flowers of antimony, glaſs, pewter, braſs, and many other chymical concretes, to be taken into the number; and then it will be evident, that to diſtinguiſh the ſpecies of natural bodies, a concourſe of accidents will be ſufficient, without conſidering any ſubſtantial form. But becauſe we need not have recourſe to inſtances of a diſputable nature, for the illuſtration of the mechanical production of forms, let us examine only that of vitriol. For, ſince nature herſelf, without the help of art, often produces that concrete, there is no reaſon why vitriol, produced by eaſy chymical operations, ſhould not be looked upon as a body of the ſame nature and kind. And in factitious vitriol, our knowing what ingredients we make uſe of, and how we put them together, enables us to judge very well how vitriol is produced. But becauſe this is uſually reckon'd, with ſalt-petre, ſea-ſalt, and ſal-gem, among true ſalts; we muſt take notice, in the firſt place, that vitriol is not a mere ſalt, but what *Paracelſus*, and, after him, others call a magiſtery; which, in their ſenſe, commonly ſignifies a preparation, wherein the body to be prepared has not its principles ſeparated, as in diſtillation, incineration, *&c.* but wherein the whole body is brought into another form, by the addition of ſome ſalt or menſtruum, united, *per minima*, with it. And accordingly, we find, that from common vitriol, whether native or factitious, may be obtained an acid, ſaline ſpirit, and a metalline ſubſtance; as copper may be ſeparated from blue vitriol. And as there is vitriol of iron, which is uſually green, and another of copper, which is blue, and alſo a white vitriol, whoſe compoſition is generally unknown; yet all of theſe are, without ſcruple, reputed true vitriols, tho' they differ ſo much in colour, and ſeveral other qualities; ſo I ſee no reaſon, why the other minerals, being reduced, by their proper menſtrua, into ſalt, like magiſteries, may not paſs for the vitriols of thoſe metals, and, conſequently, for natural bodies. If upon the filings of ſteel, we put a convenient quantity of oil of vitriol, and dilute the mixture with water, it is eaſy to obtain a vitriol of iron by cryſtallization; which fully agrees with the other vitriol, produced by nature without the help of any other menſtruum, than rain water falling upon the marcaſites. But that no ſcruple might ariſe from the menſtruum uſed in making *vitriolum martis*, I employ'd a different one, that could not be ſuſpected to have any thing of vitriol in it; and this was ſpirit of ſalt, which anſwered the ſame end. Nor will the great diſpoſition in this our vitriol to reſolve, by the moiſture of the air, into a liquor, make it eſſentially different from other vitriols; ſince it has been obſerved, that even the common vitriol in *Germany*, will alſo run *per deliquium*. To apply theſe experiments, we may conſider, firſt, that our factitious vitriol is not only endowed with many qualities common to other ſalts, as tranſparency, brittleneſs, ſolubility in water, *&c.* but ſuch as are peculiar to it, as greenneſs, eaſineſs of fuſion, ſtypticity of taſte, a peculiar ſhape, a power to ſtrike a black with infuſion of galls, an emetic faculty, *&c.* and, ſecondly, that tho' theſe qualities, are, in common vitriol, ſuppoſed to flow from

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from the ſubſtantial form of the concrete, and may, as juſtly as the qualities of other inanimate bodies, be employ'd to prove ſuch a form: yet, in our vitriol, made with ſpirit of ſalt, the ſame qualities were produced by the aſſociation of two ingredients, ſingly deſtitute of them; which enabled it to affect our organs of ſenſe, and work upon other bodies, after the manner of common vitriol. Indeed, it is ſo far from appearing, that any ſubſtantial form is here generated a-new, that there is not ſo much as an exquiſite mixture made: for both the ingredients retain their nature, and may eaſily be ſeparated by diſtillation; ſo that there is here but a juxta-poſition of the metalline and ſaline particles; only they are ſo aſſociated, as by the manner of their coalition to acquire that new texture, which denominates the magiſtery they compoſe, vitriol. PHYSICS.

The curious figures of ſalts depend not upon ſubſtantial forms.

But tho' the exact and curious figures, into which vitriol, and other ſalts, are apt to ſhoot, be made arguments of the preſence, and great inſtances of the plaſtic ſkill of ſubſtantial forms, and ſeminal powers; yet, I am not ſo fully ſatisfy'd in this matter, as the modern philoſophers appear to be. It is not that I deny *Plato*'s γεωμετρικὸς ὁ Θεὸς, to be applicable to theſe exquiſite productions of nature; for tho' God has thought fit, to make things after a more intelligible way, than by the intervention of ſubſtantial forms; and tho' the plaſtic power of ſeeds, ſeems unneceſſary in our caſe; yet the divine geometry is, nevertheleſs, to be acknowledged, for having endowed the primary corpuſcles of ſalts and metals, with a peculiar fitneſs for ſuch concretions. And, tho' I ſee no neceſſity for aſcribing ſuch productions to a plaſtic power; yet, the more elaborate and curious fabric of animals, may be aſcribed to an higher origin. But my conjectures about the figures of ſalts, will be ſupported by theſe conſiderations.

1. By a bare aſſociation of metalline and ſaline corpuſcles, a concrete, as finely figured as other vitriols, is producible; as we have already ſhewn.

2. The figures of theſe ſalts are not conſtantly the ſame, but differently varied, as they happen to ſhoot more or leſs haſtily, or in different proportions of liquor; as is manifeſt from the difference in cryſtals of vitriol, when large quantities are taken out of the great coolers. And, accordingly, where *Agricola* deſcribes the ſeveral ways of making vitriol in large quantities, he compares the concretions indifferently to cubes, or cluſters of grapes. I have ſo ordered a pure lixivium of alkalizate ſalts, from which uſed to be obtained only a white calx, that it has ſhot into tranſparent cryſtals, almoſt like white ſugar-candy. And, having diſtilled a certain quantity of oil of vitriol, with a ſtrong ſolution of ſea-ſalt, the reſidue, diſſolved in fair water, ſhot into cryſtals, ſometimes of one figure, and ſometimes of another, as the quantity and ſtrength of the oil of vitriol, and other accidents, determin'd. From ſpirit of urine and of nitre, I have ſometimes obtained, fine long cryſtals, ſhaped like ſalt-petre; and tho' ſilver, diſſolved in *Aqua fortis*, or ſpirit of nitre, uſually ſhoots into exceeding thin plates, almoſt like *Muſcovy*-glaſs; yet, I have obtained lunar cryſtals, of a different figure; each cryſtal being compoſed

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PHYSICS. of many ſmall ſolids finely ſhaped, and adhering ſo fitly to one another, as to have one ſurface common to them all.

3. Inſenſible corpuſcles of different exquiſite ſhapes, and endowed with plain, ſmooth ſides, will conſtitute bodies variouſly, but all very finely figured. And, firſt, tho' harts-horn, blood, and urine, may well be ſuppoſed to have their ſubſtantial forms deſtroy'd, by the action of the fire, in their analyſis; yet their ſaline particles will leiſurely ſhoot into cryſtals of very curious ſurfaces, and regular figures. And of theſe finely ſhaped cryſtals, of various ſizes, I have obtained ſeveral from other diſtill'd acid liquors; and particularly, with a menſtruum that would diſſolve ſome gems, and with a ſolution of coral, made in ſpirit of verdigreaſe. For the ſame reaſon, when I try'd, whether the particles of ſilver, diſſolved in *Aqua fortis*, would not, without coagulating with the ſalts, convene, upon account of their own ſhapes, into little concretions of ſmooth and flat ſurfaces; I found, that having diluted one part of the ſolution with a great many parts of diſtill'd rain-water, a plate of copper being ſuſpended in the liquor, and ſuffered to lie quiet a while, there would ſettle about it, ſwarms of little metalline bodies, ſhining in the water, like the ſcales of ſmall fiſh; but formed into little plates extremely thin, with ſurfaces not only flat, but exceeding gloſſy: and among thoſe, ſeveral of the larger were prettily figured at the edges. And the corpuſcles of gold are ſufficiently diſpoſed to convene, with thoſe of fit ſalts, into concretions of determinate ſhapes; as I have found in the cryſtals obtained from it in *Aqua regis*: and, alſo, when, by a more powerful menſtruum, I had ſubdivided the body of gold into ſuch minute particles, as to be ſublimable, theſe volatile particles, with the ſalts, wherewith they were elevated, afforded plenty of cryſtals, reſembling one another in ſhape. I have, indeed, ſometimes try'd to procure compound figures from the ſhootings of different ſalts together; but find, we muſt not expect, that in all caſes, they ſhould be totally compounded: for they often are of ſuch different natures, that one will ſhoot much ſooner than another; and then a large proportion of that will be firſt cryſtallized in its own ſhape, as is viſible in refining impure, or *Barbary* nitre, from the common ſalt wherewith it abounds. And, as *Agricola* obſerves, where a vitriolate matter is mixed with alum, thoſe two kinds of ſalt will ſhoot ſeparately in the ſame veſſel: in which caſes, all that can be expected, is, that the remaining part of the mixture ſhould afford cryſtals of compounded ſolid figures. Tho' the *Venetian* borax, ſold in the ſhops, be a known factitious body, compounded of ſeveral ſalts; yet ſome of it being diſſolved in a large quantity of fair water, and made to coagulate very leiſurely, I thence obtained cryſtals, upon whoſe ſurfaces, I could perceive very exquiſite and regular figures. We may add, that tho' the *Caput mortuum* of common *Aqua fortis* conſiſts of bodies very different in nature; yet barely by frequent ſolutions and coagulations, the ſaline particles will ſhoot into very fine figures; as triangles, hexagons, rhomboids, *&c.* no leſs exact than thoſe of the fineſt nitre or vitriol: ſome, moreover, terminate in bodies, almoſt like pyramids, conſiſting of ſeveral triangles, that meet in one point at the vertex, as admirably.

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rably shaped as the fairer sort of *Cornish* diamonds. And I have not only obtain'd new shapes by compounding saline bodies, such as sea-salt, and salt-peetre, but found them, also, producible in some natural and chymical salts, dissolved together; and, also, in saline spirits made by distillation: but only those are fit for this purpose, which work upon one another with ebullition: for in that conflict, the saline corpuscles associate together, and, by their newly acquired figure, lose much of their former volatility; so that upon evaporation of the superfluous liquor, they will not fly away, as, otherwise, they might, but coagulate together into finely-shaped crystals; as I have tried with the spirits of urine and nitre, oil of vitriol, *&c.* And, what is farther remarkable, spirit of urine satiated with spirit of salt, has often afforded me crystals, exceedingly different in shape, from those obtained with spirit of urine, satiated, either with oil of vitriol, or with spirit of nitre. For that salt, compounded of the two spirits, of urine and of common salt, usually consists of one long rod, whence, on both sides, issue out far shorter crystals, sometimes perpendicular to that, and parallel to one another, like the teeth in a comb; and, sometimes, so inclining, as to make the whole appear, almost like a feather; which is the more remarkable, because I have observed sal-armoniac, made of crude urine and common salt, with a proportion of soot, will, if warily dissolved and coagulated, shoot into crystals of the like shape. PHYSICS.

How far the unknown figure of a salt may possibly be guess'd at, by that of the figure, which it makes with some other salt, whose figure is already known, I leave others to discover.

4. Considering that vitriol was but a magistery, made by the coagulation of the corpuscles of a dissolved metal, with those of the menstruum; I thought the magisteries of other metals might, without inconvenience, be added, as other vitriolate concretes, to the green, the blue, and white vitriol, which are, without scruple, referred to the same species: but oil of vitriol being not a fit menstruum to dissolve several metals, nor even all those that it will corrode; and there being the like unfitness, also, in common spirit of salt, I pitch'd upon *Aqua fortis*, or spirit of nitre, as the menstruum, most likely to afford variety of vitriols; and, accordingly, found, that besides a curious one from copper, that liquor would, with quick-silver, afford one sort of crystals, with silver another, and with lead a third; all which crystals of vitriol, as they differ'd from each other in other qualities, so they did very considerably differ in shape; the crystals of silver shooting into exceeding thin plates, and those of lead and quick-silver obtaining figures, tho' different from each other, yet of a far greater depth and thickness, and less remote from the figure of common vitriol, or sea-salt: yet all these vitriols, especially that of crude lead, successfully made, had shapes curious and elaborate, as well as those we admire in common vitriol or sea-salt *.

If

* Sir *Isaac Newton* gives the following account of crystallization. "When any saline liquor is evaporated to a cuticle, "and let cool, the salt concretes in regular

PHYSICS. If then these curious shapes, which are supposed the strongest proofs of substantial forms, may be the results of texture; and if art can produce vitriol itself, as well as nature; are not substantial forms unnecessary in solving the ordinary phenomena; since matter, with a convention of accidents, is alone sufficient for that purpose? And why should we wilfully exclude those productions of the fire, wherein the chymist is but a servant to nature, from the number of natural bodies? Indeed, since there is no certain diagnostic agreed on, whereby to discriminate natural and factitious bodies, and constitute the species of both; we might certainly draw arguments from the qualities and operations of several of those, which are called factitious bodies, to shew how much may be ascribed to, and performed by the mechanical characteristics or stamps of matter. And, if we admit these productions into the number of natural bodies, they will afford us a multitude of instances to shew, that bodies may acquire many noble qualities, barely, by having mechanical properties introduced by outward agents into their matter, or destroy'd there. Even those, who embrace *Aristotle*'s principles, confess, that a slight change of texture, without the introduction of a substantial form, may not only make a specific difference betwixt bodies; but so vast an one, that they shall have differing genus's, and (as the chymists speak) belong to different kingdoms. For coral, whilst it grows at the bottom of the sea, is a real plant, and hath often been there found soft, tender, and juicy; it, also, propagates its species, as well as other shrubs; yet, being gathered, and removed into the air, it turns to a stony concretion. And a much stranger thing may be seen in the island of *Sombrero* in the *East-Indies*, not very far from *Sumatra*, if we may believe Sir *James Lancaster*, who relates it as an eye-witness; for which reason, I shall add the story in his own words. "Upon the coast of *Sombrero*," says he, "we found upon "the sand, by the sea-side, a small twig growing up to a young tree; and "offering to pluck up the same, it shrunk down into the ground, and "sinketh, unless you hold very hard. And being plucked up, a great "worm is the root of it; and look how the tree groweth in greatness, the "worm diminisheth. Now as soon as the worm is wholly turned into the "tree, it rooteth in the ground, and so groweth to be great. This transformation was one of the greatest wonders I saw in all my travels. This "tree being plucked up a little, the leaves stripped off and the peel, by "that time it was dry, turned into an hard stone, much like to white coral: so that this worm was twice transformed into different natures. Of "these we gathered, and brought home many." *Piso*, in his history of *Brasil*, appeals to a multitude of witnesses, for the ordinary transformation of a sort of animals, not much unlike grashoppers, into vegetables, at a

"lar figures; which argues, that the particles of the salt, before they concreted, "floated in the liquor at equal distances "in rank and file, and, by consequence, "that they acted upon one another by "some power, which, at equal distances is "equal, at unequal distances unequal. For "by such a power, they will range themselves uniformly; and without it, they "will float irregularly, and come together "as irregularly." *Newton. Optic.* p. 363.

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certain ſeaſon of the year. And Father *Michael Boym* affirms, that he ſaw in a ſmall ſhallow freſh-water lake of the iſland *Hainan*, (which belongs to *China*) crabs, or craw-fiſh, which, as ſoon as they were drawn out of the water, loſt both life and motion in a moment, and became petrified; tho' nothing appeared to be changed, either in the external, or internal figure of their bodies. PHYSICS.

SECT. V.

Experiments to ſhew the origin of forms, from the renewing of bodies.

HAving diſpatch'd the firſt argument, whereby I propoſed to confirm the origin of forms, from the manner, by which ſuch a convention of accidents, as deſerves to paſs for a form, may be produced; I proceed to the ſecond proof I deſign'd of the ſame, drawn from the re-production of a phyſical body. And this argument of the two is the moſt concluſive. For if we can re-produce a body, which has been deprived of its ſubſtantial form, it ſeems more than probable, that the form, which gives being and denomination to a concrete, may be, in ſome bodies, but a modification of the matter they conſiſt of, whoſe parts, by a peculiar diſpoſition to each other, conſtitute ſuch a determinate ſubſtance, with particular properties; whereas, if the ſame parts were otherwiſe diſpoſed, they would conſtitute other bodies of very differing natures from that of the concrete, whoſe parts they formerly were; and which may again reſult, or be produced after its diſſipation, and ſeeming deſtruction, by the re-union of the ſame component particles, aſſociated in their former manner. But tho' an adequate renewal of a body, chymically analyzed, be difficult, becauſe of the diſſipation of ſome parts in the proceſs; yet ſuch a re-production as is practicable, may ſuffice for our purpoſe. For even in ſuch experiments, it appears, that by the bare re-union of ſome parts, the very ſame matter, without addition, may be brought again to conſtitute a body of the like nature with the former, tho' not of equal bulk.

In this manner we attempted the diſſipation and re-union of the parts of common amber: and tho' chymiſts, for fear of breaking their veſſels, when they commit it to diſtillation, add ſand, brick-duſt, *&c.* thereto, yet we found, that if the retort were not too full, and the fire ſlowly and warily applied, the addition of any other body was needleſs. Wherefore, having put into a glaſs-retort, four or five ounces of amber, and applied a gentle, gradual heat, we obſerved the amber to melt and bubble; and having ended the operation, and ſever'd the veſſels, there was come over, in the form of oil, ſpirit, phlegm, and volatile ſalt, near half the weight of the concrete: upon breaking the retort, we found in the bottom of it, a cake of coal-black matter, whoſe upper ſurface was ſo exquiſitely poliſhed, as to fit it to ſerve for a looking-glaſs; and this ſmooth maſs being broken, the larger fragments appeared with an excellent luſtre. All theſe parts of the amber, being again put together, into a glaſs-body, with a blind head luted to it, were placed in ſand, to be incorporated by a gentle heat; but the fire having been raiſed too high, it forced the veſſel out of the ſand, and broke off the top,

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PHYSICS. top. The remaining matter, resembling tar, was capable of being, with a gentle heat, poured out like a liquor; and, when cold, it would stick to the fingers: yet this opened body will not communicate so much as a tincture to spirit of wine; but with oil of turpentine, it dissolves into a blood-red balsam, useful, perhaps, in chirurgery.

In our attempts to renew vitriol, turpentine, and some other concretes, we found more difficulty, than every one would expect. The bodies, on which such experiments are likeliest to succeed, seem to be alum, sea-salt, and vitriol. Tho' we found it troublesome to take the principles of alum asunder, without a mixture of some foreign matter, which would hinder the restoration of the separated parts. So, likewise, if sea-salt be distilled, as usual, with thrice its weight of burnt clay, or beaten brick, that will prove inconvenient in its redintegration; and if it be distill'd alone, it is apt to flux by heat, and whilst it remains in fusion, will scarce yield any spirit at all. As for vitriol, tho' the redintegration of it might seem to be less hopeful, than that of the other salts, because it consists not only of a saline, but of a metalline body; yet, as there needs no *caput mortuum* in the distillation of it, we made two or three attempts, and seemed to miss rather upon account of accidental hindrances, than of any insuperable difficulty in the thing itself: for in our attempts to re-unite the liquors forced off by distillation, with the *caput mortuum*, we sometimes obtained shoots of pure vitriol. I likewise, digested, for several weeks, a quantity of powdered antimony, with a greater weight by half of oil of vitriol; and having committed this mixture to distillation, obtained, besides a little liquor a considerable quantity of combustible antimonial, or antimonio-vitriolate sulphur; there remaining at the bottom of the retort, a light, and very friable *caput mortuum*, all the upper part of which was as white as common wood-ashes, while the rest looked like a cinder. This *caput mortuum* we committed to a naked fire, in a small glass-retort, well coated, and accommodated with a receiver, for many hours; and, at length, disjoining the vessels, we found no antimonial quick-silver, and much less of sulphur sublimed than we expected. The *caput mortuum* was fluxed into a mass, covered with a thin cake of glass; fragments whereof being held against the light, were as colourless as common white glass. The lump above-mentioned being broken, was found to be perfect black antimony, adorned with long shining streaks, like common antimony; only this seemed to have been a little refined, by the sequestration of its unnecessary sulphur; which ingredient seems, by this experiment, to abound more in some particular parcels of that mineral, than is absolutely requisite to the constitution of antimony. But among all my trials, about the redintegration of bodies, that which seemed to succeed best, was made upon turpentine: for having taken some ounces of this, very pure, and good, and put it into a glass-retort, I distill'd it with a very gentle fire, till it was separated into a large quantity of very clear liquor, and a *caput mortuum*, very dry and brittle; then breaking the retort, I powdered the *caput mortuum*, which, when taken out, was transparent, exceeding flack, and very red; but being powdered, appeared of a pure yellow colour.

This

This powder we carefully mixed with the liquor diſtill'd from it, which immediately diſſolved part of it into a deep red balſam: but by farther digeſtion in a large glaſs exquiſitely ſtopped, that colour began to grow fainter; tho' the remaining part of the powder was perfectly diſſolved, and ſo well re-united to the more fugitive parts of the concrete, that ſcarce any perſon, by the ſmell, taſte, or conſiſtence, would take it for other than good turpentine. PHYSICS.

SECT. VI.

Obſervations and experiments to ſhew the origin of forms and qualities.

THUS I have endeavoured to give the ſubſtance of the corpuſculan philoſophy, as far as is neceſſary towards underſtanding the productions and changes of particular qualities. And as theſe principles are built upon the phenomena of nature, and deviſed in order to explain them, I think proper to add, by way of recommendation thereof, ſuch facts as led me to this doctrine, or as I was directed to diſcover by the notions I had embraced. And ſince I appeal to the teſtimony of nature, I ſhall ſet down ſome obſervations of what ſhe does without aſſiſtance, and ſome experiments wherein ſhe is guided by art. The obſervations will be the more ſuitable to our deſign, for being common and familiar; and the experiments, for being few in number, and pregnant in phenomena.

1. The firſt obſervation ſhall be fetched from what happens in an egg, which undergoes very great changes, when it is by incubation turned into a chick. A prolific egg contains two liquors, each of them apparently ſimilar: for tho' the white and the yolk ſeem to be diſſimilar, by the different ſubſtances they afford in diſtillation; yet it would be hard to prove, that one part of the white, for inſtance, will not be made to yield the ſame different ſubſtances by diſtillation, with any other part of the ſame: and bones themſelves, with other hard parts of a human body, which are confeſſedly ſimilar, will, by diſtillation, afford ſalt, phlegm, ſpirit, oil, and earth, as well as the white of an egg. Now, by bare concuſſion, this white may be reduced from a tenacious, to a fluid body: and the rudiments of the chick, lodg'd in the cicatricula, are nouriſhed only by the white for ſome time; the yolk being, by providence, reſerved as a more ſolid aliment, when the creature is grown ſtrong enough to digeſt it; ſo that we may ſee the chick furniſhed with head, wings, legs, beak, claws, *&c.* whilſt the yolk appears untouched. But whether this obſervation about the entireneſs of the yolk, be preciſely true, it is not very material; ſince the yolk itſelf, being, likewiſe, a ſimilar fluid, is ſufficient for the preſent purpoſe. Now, the nutritive liquor of an egg, being brooded on by the hen, will, within two or three weeks, be tranſmuted into a chick, furniſhed with organical parts, as eyes, ears, wings, legs, *&c.* of a very differing fabric; and with a great number of ſimilar ones, as bones, cartilages, ligaments, tendons, membranes, *&c.* which differ much in texture from one another; beſides the liquors, as blood, chyle, gall, *&c.* contained in the ſolid parts. In a word, we-

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PHYSICS. we have here produced, out of ſuch an uniform matter, as the white of an egg, firſt, many new kinds of qualities, as colours, odours, taſtes, heat, hardneſs, ſmoothneſs, roughneſs, *&c.* ſecondly, qualities uſually diſtinguiſhed from ſenſible ones, as fluidity, conſiſtence, flexibility, ſpringineſs, *&c.* and, thirdly, occult properties, ſince, as phyſicians obſerve, ſome birds afford ſpecific medicines in the falling-ſickneſs, hyſteric fits, and other diſtempers.

If it be here alledged, that the chick, with all its parts, is not an engine mechanically contriv'd, but faſhion'd out of matter by the ſoul of the bird, lodged chiefly in the cicatricula, which by its plaſtic power faſhions the obſequious matter, and becomes the architect of its own manſion; I anſwer, that this invalidates not what I intend to prove from it: for, let the plaſtic principle be what it will, yet being a phyſical agent, it muſt act after a phyſical manner; and having no other matter to work upon, but the white of an egg, it can, conſequently, only divide the matter into minute parts of ſeveral ſizes and ſhapes, and, by local motion, variouſly contex them, according to the exigency of the animal to be produced; tho' from ſo many various textures of the produced parts, there muſt naturally reſult various differences of colours, taſtes, conſiſtences, and many other qualities. We are here to conſider, not what is the agent, or efficient, in theſe productions; but what is done to the matter that affords them. And tho' ſome birds, by an inbred ſkill, very artificially build their neſts; nature only enables them to ſelect the materials thereof, and, by local motion, to divide, tranſport, and connect them after a certain manner. And, when man himſelf, who is, undoubtedly, an intelligent agent, is to raiſe a building, or form an engine, he may, indeed, by the help of reaſon and art, ſkilfully contrive his materials; ſtill, all he can do, is but to move, divide, tranſpoſe, and ſet together the ſeveral parts, into which he is able to reduce the matter aſſigned him. Nor need we imagine, that the ſoul of that hen, which having firſt produced the egg, after a while ſits on it, hath any peculiar efficiency in hatching of a chick; for the egg might be as well hatch'd by another hen, tho' that which laid it were dead: nay, in ſome places, eſpecially in *Ægypt*, there needs no bird at all to produce a chick out of an egg, where multitudes of eggs are hatch'd by the regulated heat of ovens and dunghills.

2. Water being eſteemed an elementary body, and far more homogeneous than any other fluid; it will make very much for our purpoſe, to ſhew, that by a different texture of its parts, it may be brought to conſtitute bodies of very different qualities. And this it does by nouriſhing vegetables: for thus all, or the greateſt part, of that which would accrue to a vegetable ſo nouriſhed, appears to have been materially water; with what foreign quality ſoever it may afterwards, when tranſmuted, be endowed. *Helmont* mentions an experiment of this nature, made with a willow, ſet in a pot of earth, which for ſeveral years he fed with rain-water. And we may conjecture at the eaſy tranſmutableneſs of water, by what happens in gardens and orchards,

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chards, where the ſame ſhowers of rain, after a long drought, cauſe a great number of differing plants to flouriſh. But theſe things do not fully reach our caſe, becauſe it may be objected, that rain-water cauſes not theſe plants to thrive and flouriſh, by immediately affording them the aliment they aſſimilate into their own ſubſtance; but by proving a vehicle to the ſaline ſubſtances of the earth, itſelf being inſenſibly, afterwards, exhaled in vapour. And, indeed, experience ſhews us, that ſeveral plants, which thrive not well without rain-water, are not yet nouriſhed by it alone; ſince when corn and fruit-trees have conſumed the ſaline and ſulphureous juices of the earth, they will not proſper there, how much rain ſoever falls upon the land, till by dung or otherwiſe, it be again ſupplied with proper juices. Wherefore I attempted to make plants grow in vials fill'd with nothing but water; and found, that *vinca pervinca*, *raphanus aquaticus*, ſpear-mint, and even *ranunculus*, grew and proſper'd very well therein; yet ſome of theſe were only ſlips without roots. Several were left in the water all the autumn, and a great part of the winter; and at the end of *January*, were taken out green, and with fair roots, which they had ſhot in the water: particularly a branch of *raphanus aquaticus*, was kept full nine months; and during that time withered not, tho' it paſs'd the whole winter; and was taken out with many fibrous roots, ſome green buds, and an increaſe of weight. A ſtump of ranunculus proſpered in the water ſo, that, in a month's time, it attained to more than double the weight it had when firſt put in. And another piece of ranunculus being taken out ſix months after it was put in, weighed almoſt a dram and an half, which was above thrice as much as it did at firſt: and this circumſtance demonſtrates a real aſſimilation and tranſmutation of water into the ſubſtance of the vegetable. Hence I infer, that the ſame corpuſcles, which, convening together after one manner, compoſe that fluid, inodorous, colourleſs, and inſipid body, water, being ranged after a different manner, may conſtitute different concretes, poſſeſs'd of firmneſs, opacity, odours, taſtes, colours, and ſeveral other manifeſt qualities; and theſe too very different from one another. Beſides, theſe diſtinct portions of tranſmuted water may have many other qualities, without excepting thoſe, which are called ſpecific or occult; witneſs the ſeveral medicinal virtues attributed to ſpear-mint, to vinca pervinca, marjoram, and *raphanus aquaticus*. If it be here pretended, that the ſolid ſubſtance accruing to a plant in water, proceeds not from the water itſelf, but from the nitrous, fat, and earthy ſubſtances, which may be preſumed to abound, even in common water; I reply, that, tho' as to ſeveral plants, which flouriſh after rain, I am apt to think, they may, in part be nouriſhed, as well by the ſaline and earthy ſubſtances, to which the rain uſually proves a vehicle, as by the rain itſelf; yet as to plants which grow in glaſſes filled with pure water, this ſhould not be barely aſſerted, but proved*; which,

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* Dr. *Wood-ward* has made ſeveral curious experiments, to ſhew, that mere elementary water will not ſuffice for the vegetation of plants; but that a terreſtrial matter contain'd in, and, by repeated filtration, diſtillation, &c. not wholly ſeparable from its vehicle, water, is abſolutely neceſſary thereto. See *Philoſ. Tranſ.* N°. 253. p. 193—207.

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PHYSICS. perhaps, is not eaſy to be done, conſidering how vaſt a quantity of fair water muſt be exhaled away, to obtain even an ounce of dry reſidence, whether ſaline or earthy.

3. That a plant growing in the earth doth attract, by virtue of its vegetative ſoul, the juices of the earth within its reach, and ſelecting the parts agreeable to its nature, refuſe the reſt, is the general opinion; and, therefore, many are not ſurprized, when a tree bears fruit, that is ſour or bitter, becauſe they preſume, nature, in the root of the tree, has culled out ſuch parts of the alimental juice of the earth, as, convening into fruit, are fit to give it ſuch a quality. But it is worth obſerving, for our preſent purpoſe, what happens, both in ordinary graftings, and eſpecially in inoculation: for tho' we may preſume, that the root of a white-thorn, may electively attract its aliment from the earth, to produce the fruit, which is proper to it; yet we cannot ſuppoſe, that it ſhould, in its attraction of aliment, have any deſign of providing an appropriate nutriment for a pear: but, we know, that the cions of a pear-tree will take very well upon a white-thorn-ſtock, and yield fruit, very different, in many qualities, from that of the white-thorn. And, tho' apples and pears are ſeldom propagated but by grafting, yet they may be ſo by inoculation; which ſeems to be but a kind of grafting with a bud. Now, in the inoculations, made upon fruit-trees, it is obſervable, that a little vegetable bud, often not ſo big as a pea, is able ſo to tranſmute all the ſap which arrives at it; that, tho' this ſap be already in the root, and, in its paſſage upwards, determined by nature's intention, as men ſpeak, to the production of fruit, natural to the ſtock; it ſhould yet, by ſo ſmall a vegetable ſubſtance, be ſo far changed, as to conſtitute a fruit quite otherwiſe qualified, than the genuine product of the tree; which, at the ſame time, is actually produced by thoſe other portions of the like ſap, that happened to nouriſh ſuch prolific buds, as are the genuine off-ſpring of the ſtock: ſo that the ſame ſap, which, in one part of a branch, conſtitutes a cluſter of haws, in another part of the ſame branch, may conſtitute a pear. And, what is farther remarkable, not only the fruits made of the ſame ſap, often differ from one another, in ſhape, bigneſs, colour, odour, taſte, and other obvious qualities; but tho' the ſap itſelf, by a wateriſh, and, almoſt, inſipid liquor; yet it is not only convertible, by buds of ſeveral natures, into different fruits, but in one and the ſame fruit, the tranſmuted ſap, ſhall, by different textures, be made to exhibit very different, and ſometimes contrary qualities. As when a peach-bud not only changes the ſap, which comes to it, into a fruit, very differing from that, which the ſtock naturally produces; but into parts very different from one another in the ſame fruit. From inoculations, therefore, we learn, that a liquor ſeemingly homogeneous, may, by being variouſly ſtrain'd, be tranſmuted into bodies, endowed with new ſcents, colours, taſtes, ſolidity, medicinal virtues, and many other qualities, manifeſt and occult. If it be ſaid, that theſe qualities are the productions of the plaſtic power, reſiding in prolific buds, the ſame anſwer will ſerve, as to the like objection in the firſt obſervation.

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4. The laſt obſervation I ſhall, at preſent, mention, is, of rotten cheeſe: for if we take notice of the difference betwixt two parts of the ſame cheeſe, whereof the one continues ſound, by preſerving its texture, whilſt the other hath ſuffered that alteration we call rottenneſs; we may, often, ſee a manifeſt change in the ſeveral portions of a body, which was before ſimilar; for the rotten part will differ from the ſound in its colour, its odour, its taſte, and ſeveral other qualities: and if, with a good microſcope, we view the mouldy parts of ſome cheeſes, we ſhall diſcover therein ſwarms of little animals, furniſhed with variety of parts of different ſizes, ſhapes, textures, &c. and perceive a yet greater diverſity, as to manifeſt qualities, betwixt the mouldy part of the cheeſe, and the untainted, than were viſible to the naked eye. PHYSICS.

SECT. VII.

Experiments to ſhew the nature of qualities: and firſt, camphire ſuddenly reſtored, after it ſeem'd to be deſtroy'd.

WE come now to our experiments about qualities.

1. Into good clear oil of vitriol, throw a convenient quantity of camphire, groſly beaten, and, after a while, it will run into a liquor; and, by ſhaking, mix with the oil; as, alſo, impart thereto, firſt a yellow, then a red colour, and, at laſt, bring it to be opake and ſcentleſs: but, if into this liquor, be poured a due proportion of fair water, it immediately becomes pale, and the camphire emerges in its own nature and form, white, combuſtible, and odorous.

The phenomena of this experiment afford us ſeveral particulars to our preſent purpoſe. (1.) We here ſee a light conſiſtent body, brought, by comminution, to ſwim and mix with a heavy liquor, on which it floated before; but as gold diſſolv'd in *Aqua regia*, is thereby kept from ſinking, theſe inſtances, compared together, ſhew, that when bodies are reduced to very minute parts, we muſt as well conſider their particular texture, as the received rules of hydroſtatics, in determining whether they will ſink, or float. (2.) This experiment alſo ſhews, that ſeveral colours, and even a very deep one, may ſometimes be produced by a white body, and a clear liquor; and that without the intervention of fire, or any external heat. (3.) That this colour may be deſtroy'd, and the whiteneſs reſtored by the addition, only, of fair water; which, alſo, receives neither the colour it deſtroy'd, nor that it reſtored. For, (4.) the opacity of the ſolution preſently vaniſhes, and that menſtruum, with the water, makes up (as ſoon as the corpuſcles of the camphire come to float) one tranſparent liquor. (5.) It is alſo worth noting, that upon the mixture of a liquor, which renders the whole much lighter, a body is made to emerge, that did not ſo before. And here I cannot but obſerve, how little the ſchool-diſtinction, of elements loſing their forms in mixed bodies, is favoured by this experiment; wherein even a mixed body (for ſuch is camphire) doth, in a farther mixture, retain its form and nature, and may be immediately ſo divorced from the body, to which it was united, as to return, in a moment, to the manifeſt exerciſe of its former qualities. (6.) But the notableſt thing in the experi-

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PHYSICS. ment, is, that odours ſhould depend ſo much upon texture; that one of the ſtrongeſt-ſcented drugs, ſhould quite loſe its ſcent, by mixing with a body that hath none of its own. (7.) Nor is it leſs conſiderable, that ſo ſtrong a ſcent ſhould be produced in a mixture, wherein none could be perceived before, by ſuch a liquor as water; which is quite deſtitute of any odour. And ſo eaſy a reſtoration of the camphire to its native ſcent, as well as other qualities, likewiſe argues, that the union or texture of the two ingredients, the camphire and the oil of vitriol, was but very ſlight; upon which, nevertheleſs, a great alteration, in point of qualities, enſues. And to confirm that ſeveral of the preceeding phenomena depend upon the particular texture of the liquors here employ'd, it may be obſerved, that if inſtead of oil of vitriol, ſpirit of nitre be made uſe of; not a red or dark, but a tranſparent and colourleſs ſolution will enſue. And when to the above-mentioned red mixture, I put, inſtead of fair water, about two or three parts of duly rectified ſpirit of wine, there would follow no ſuch changes; but the ſpirit of wine, that acquires no colour by diſſolving the concrete apart, yet took out of the mixture its adventitious colour, which ſubſiſted not before in either ingredient. But by proſecuting the experiment a little farther, we made it afford us ſome new phenomena. For, (8.) having kept the mixture in a warm place, and diſtill'd it out of a glaſs-retort, the liquor which came over, had a ſtrong ſcent, quite different both from that of the mixture and the camphire; the remaining maſs being coal-black, and ſome of its parts looking like poliſhed jet: which is the more conſiderable, becauſe tho' vegetable ſubſtances uſually acquire a blackneſs from the fire; yet, neither liquors that have already been diſtill'd, obtain that colour upon rediſtillation, nor have we, upon trial, found, that camphire expoſed to the fire in a retort, fitted with a receiver, would at all acquire a jetty colour. (9.) We farther learn by this experiment, that notwithſtanding the great volatility of camphire, yet here it is ſo reſtrained, that the *caput mortuum*, juſt mentioned, endured a ſtrong fire in the retort, before it was reduced to that pitchy ſubſtance: and, afterwards, bore a much ſtronger, for above half an hour, in a covered crucible, without yielding any ſcent: ſo much do the fixity and volatility of bodies depend upon texture.

Changes made by ſublimate upon copper. 2. Among many experiments made with ſublimate, to manifeſt, that new qualities are producible in bodies, as the effects of new textures, I ſhall here only produce ſuch wherein copper, ſilver, and gold, were uſed. And, firſt, we took half a pound of copper-plates, each about an inch broad, and of the thickneſs of a grain of wheat, and of any length; then caſting a pound of groſly-beaten *Venetian* ſublimate into the bottom of a deep glaſs-retort, we placed the copper-plates upon it, that the fumes of the ſublimate might, in their aſcent, act upon the metal; and fixing this retort deep in a ſand-furnace, and adapting to it a ſmall receiver, we gave it a gradual fire for ſeven or eight hours, and at length increaſed the heat. The ſucceſs was, (1.) there came little or no liquor over, but the neck and upper part of the retort were candied on the inſide, by the ſublimate adhering to them, in quantity above ten ounces; and in the retort, we found two ounces and

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a quarter of running mercury. (2.) Upon increaſing the fire, the melting matter made a noiſe in the retort, not unlike that of a boiling pot; and this we found to be a more conſtant circumſtance, than the revival of the mercury; for upon another trial, with the former proportions, we found but a few grains of it either in the retort or receiver. (3.) The metalline lump at the bottom of the retort increaſed in weight above two ounces; ſome of the copper-plates, lying at the bottom of the maſs, yet retained their figure, and malleableneſs; which we aſcribed to their not having been thin enough, to be ſufficiently wrought upon by the ſublimate: the others, which were much the greater number, had wholly loſt their metalline form, and were melted into a very brittle lump, which I can compare to nothing more fitly than a lump of good benjamin: for this maſs, tho' ponderous, was no leſs brittle, and being broken, appeared of various colours, which ſeemed to be almoſt tranſparent, and in ſome places it was red, in others of a high amber colour, and in others again, darkiſh and mixed. (4.) But this maſs being broken into ſmaller lumps, and laid upon a ſheet of white paper in a window, was, by the next morning, covered with a lovely greeniſh blue, almoſt like that of the beſt verdigreaſe; and the longer it lay in the air, the more of the internal parts of the fragments paſſed into the ſame colour: but the white paper, which, in ſome places they ſtained, ſeemed dyed of a green colour, inclining to yellow. (5.) In ſome trials we obſerved, that little copper-plates, from which the ſublimate had been drawn off, retain'd their ſhape and metalline nature, but were whitened over like ſilver, and continued ſo for ſeveral months; and upon breaking them, we found this ſilver colour had penetrated quite through them, and appear'd more beautiful in the very body of the metal, than on its ſurface. (6.) In this metalline gum, the body of the copper appeared ſo changed, and opened, that when caſt upon a coal, and a little blown, it would partly melt and flow like roſin, and partly flame and burn like ſulphur; and ſo inflammable was it, that held to a candle, or a piece of lighted paper, it would, almoſt in a moment, take fire, and flame like common ſulphur; only it ſeemed to incline more to a greeniſh colour. PHYSICS.

We next made the experiment with ſublimate and ſilver; wherein were taken of the pureſt coined ſilver, ten thin plates, on which we caſt double the weight of ſublimate, in a ſmall and ſtrongly-coated retort. This matter being ſublimed in a naked fire, we found the ſublimate almoſt totally aſcended to the top, and neck of the retort; in the latter of which appeared ſome revived mercury: at the bottom of the retort, was found a little fluxed lump of matter, which it was ſcarcely poſſible to ſeparate from the glaſs; but having, with much ado, divorced them, we found it brittle, of a pale yellowiſh colour, about the weight of the metal on which the ſublimate had been caſt; and in the thicker part of this lump, there appeared, when broken, ſome part of the ſilver plates, which, tho' brittle, ſeemed not to have been perfectly diſſolved. This roſin of ſilver, did, like that of the copper, but more ſlowly, imbibe the moiſture of the air; and within about twenty four hours, was covered with a greeniſh duſt: ſome ſmall fragments *Upon ſilver.*

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PHYSICS. of this roſin being caſt upon red-hot coals, waſted themſelves in a flame, not very different, in colour, from that of the roſin of copper, but proved more durable, than one would have expected from ſo ſmall a quantity of matter. But ſuſpecting that the copper, uſually mixed as alloy with our coined ſilver, might have too much influence here, we afterwards try'd it with refined ſilver, which but little altered the ſucceſs. And it is remarkable, as ſilver is a fixed metal, and accounted indeſtructible, that it ſhould, by ſo ſlight an operation, and with ſo ſmall an addition of other matter, be ſo ſtrangely diſguiſed, and have its qualities ſo altered. For, firſt, tho' pure ſilver and ſublimate, are both eminently white, yet the maſs we are ſpeaking of, was partly of a lemmon or amber colour, or a deep amethyſtine, and partly of ſo dark an one, that it appeared black; and ſometimes in a fragment, which ſeemed to be one continued piece, the upper part would be of a light yellow, and the lower very obſcure, and almoſt black. Next, whereas ſilver is one of the moſt opake bodies in nature, and ſublimate a white one, the produced maſs was, in a great part, tranſparent, like good amber. Thirdly, the texture of the ſilver was exceedingly altered; for inſtead of being flexible, it appeared like horn, and more apt to crack and break, than bend. Fourthly, tho' ſilver will long endure the fire before it be brought to fuſion, our mixture would eaſily melt, not only upon quick-coals, but in the flame of a candle; tho' this roſin, or gum of our fixed metal, did not, like that of copper, tinge the flame of a candle, or produce, when laid on glowing coals, either a green or bluiſh colour.

And upon gold. But farther to diſcover how much theſe operations of the ſublimate on copper and ſilver depend upon the particular texture of the bodies, I took two parcels of gold, the one common, in thin plates, and the other very well refined; and having caſt each of theſe into a diſtinct urinal, upon no leſs than thrice its weight of groſly-beaten ſublimate, I cauſed the ſublimate to be, in a ſand-furnace, elevated from the gold; but found not, that either of the two parcels of that metal was manifeſtly altered thereby: whether in caſe, the gold had been reduced to very minute particles, ſome kind of change might have been made in it, I will not ſay; but am confident, that theſe operations depend very much upon the particular texture of the body, from whence the ſublimate is elevated. Such experiments may probably be farther improved, by employing various and new kinds of ſublimate. And to ſhew that ſeveral other things may be ſublimed up together, either with crude mercury, or with common ſublimate, this inſtance may be added. Having cauſed about equal parts of common ſublimate, and ſal-armoniac to be well powdered, and incorporated; by ſubliming the mixture in ſtrong and large urinals, placed in a ſand-furnace, we obtained a new kind of ſublimate, differing from the former: for dropping a little reſolved ſalt of tartar upon the ſolution of common ſublimate, it immediately turns of an orange-tawny colour; but dropping the ſame liquor upon the ſolution of the armoniac ſublimate, it preſently changed into a liquor reſembling milk. And having, from four ounces of copper-plates, drawn ſix ounces of this new ſublimate, after the aforeſaid manner, we had in the bottom of the retort

tort a cupreous roſin, not much unlike that made by copper and common ſublimate; and this roſin, did, like the other, begin, in the moiſt air, ſoon to degenerate into a kind of verdigreaſe: but it was ſingular in this operation, that not only ſome of the ſublimate had carried up, to a conſiderable height, enough of the copper to be manifeſtly coloured by it, of a fine bluiſh green; but into the receiver there was paſſed near an ounce of liquor, which ſmelt almoſt like ſpirit of ſal-armoniac, and was tinged like the ſulimate: yet I judged not this way the moſt effectual for improving common ſublimate; being apt to think, that it may, by convenient liquors, be ſo far advanced, as to be made capable of opening the body of gold itſelf, and produce it in ſuch changes, as chymiſts often in vain attempt. PHYSICS.

3. Another experiment to ſhew how the like qualities in bodies may be produced by different ways; provided a like change of texture be made by them, we have from the proceſs of the *Luna cornea*; in which we take refined ſilver, beaten into thin plates, and diſſolving it in about twice its weight of good *Aqua fortis*, filtrate the liquor carefully to obtain a clear ſolution: into this we drop good ſpirit of ſalt, till it will no more curdle; then putting the whole mixture in a glaſs-funnel, lined with cap-paper, and letting the moiſture drain through, we dry, with a gentle heat, the ſubſtance that remains in the filtre; firſt waſhing it from the looſly-adhering ſalts, by letting fair water run through it ſeveral times, whilſt it yet continues in the filtre. This ſubſtance, being well dried, we put into a glaſs vial, which we ſet upon quick-coals, firſt covered with aſhes, and then freed from them, and melt the contained ſubſtance into a maſs, which kept for a while in fuſion, gives us the *Luna cornea*. If we firſt reduce the ſilver into cryſtals, and afterwards proceed with ſpirit of ſalt, in the manner deſcribed, we have the exceedingly opake, malleable, and hardly fuſible body of ſilver, by the convenient interpoſition of ſome ſaline particles, not amounting to the third part of the weight of the metal, reduced into cryſtals, which both ſhoot in a peculiar and determinate figure, differing from thoſe of other metals, and are, alſo, tranſparent and brittle, and much more eaſily fuſible, than ſilver itſelf; not to mention other qualities. *The proceſs of the* Luna cornea.

Here we obſerve, (1.) That tho' ſpirit of ſalt be an highly acid liquor; and tho' acid liquors and alkalies have quite contrary operations, the one precipitating, what the other would diſſolve, and diſſolving what the other would precipitate; yet, in this caſe, as neither oil of tartar *per deliquium*, nor ſpirit of ſalt will diſſolve ſilver; ſo, both the one and the other, precipitate it: which may paſs for a proof, that the precipitation of bodies depends not upon acid or alkali, but upon the texture of the bodies, which happen to be mixed. (2.) We here find, that whiteneſs and opacity may be immediately produced by liquors, both of them tranſparent and colourleſs. (3.) That a white powder may, by a gentle heat, be reduced into a maſs, indifferently tranſparent, and of a fair yellow. (4.) That tho' ſilver requires ſo ſtrong a fire to melt it, and may be long kept red-hot, without being brought to fuſion; yet, by the aſſociation of ſome ſaline particles, conveniently mixed therewith, it may be made ſo fuſible, as to be quickly melted, either

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PHYSICS. either in a thin vial, or at the flame of a candle, where it will flow almoſt like wax. (5.) It may, alſo, be noted, that tho' the ſolution of ſilver, and the ſpirit of ſalt, would, either of them a-part, have readily diſſolved in water; yet, when they are mixed, they, for the moſt part, coagulate together into a ſubſtance, which will lie undiſſolved in water; and is ſcarce ſoluble either in *Aqua fortis*, or ſpirit of ſalt. (6.) It is remarkable, that the body of ſilver being very flexible, and malleable, it ſhould yet, by the addition of ſo ſmall a proportion of ſalt, be made of a texture ſo different from that of either of its ingredients; being wholly unlike, either a ſalt or a metal, and very like in texture to a piece of horn. And to ſatisfy myſelf how much the toughneſs of this metalline horn depended upon the texture of the compoſition, reſulting from the reſpective textures of the ſeveral ingredients, I precipitated a ſolution of ſilver with the diſtill'd ſaline liquor, commonly called oil of vitriol, inſtead of ſpirit of ſalt; and having waſhed the precipitate with common water, I found, that by being fluxed in a moderate heat, it afforded a maſs, in appearance, like the concrete we are ſpeaking of; but wanting its toughneſs, being brittle enough to be eaſily broken. (7.) And tho' a ſolution of ſilver is the very bittereſt of liquors, and the ſpirit of ſalt far ſourer than the ſharpeſt vinegar; yet theſe two liquors are ſoon eaſily reduced into an inſipid ſubſtance; notwithſtanding the ſalts, which made both the ſilver, and the precipitating ſpirit ſo ſtrongly taſted, remain aſſociated with the metal. And, laſtly, it is very ſtrange, that tho' the ſaline corpuſcles, which give the efficacy both to *Aqua fortis*, and to ſpirit of ſalt, are not only ſo volatile, that they will eaſily be diſtilled with a moderate fire, but ſo fugitive, that they will in part fly away of themſelves in the cold air; yet, by virtue of the new texture they acquire, in aſſociating themſelves with the corpuſcles of the ſilver, they obtain a ſufficient degree of fixedneſs to endure melting with the metal. Nor in melting this maſs in a thin vial, could I perceive any ſenſible evaporation of the matter: nay, having afterwards put a parcel of it upon a quick coal, it ſuffered fuſion, and ran off, without appearing to be other than *Luna cornea*, as it was before.

Unuſual phenomena of a new and ſurprizing ſalt.

4. I ſhall next produce the phenomena ariſing in the proceſs of a ſalt, which, contrary to my cuſtom, I muſt conceal. And, firſt, tho' the ſeveral ingredients of this ſalt were purely ſaline, and more ſo than brine, or ſourer than the ſtrongeſt vinegar; yet the compound is ſo far from being eminently ſalt, ſour, or inſipid, that it is rather ſweet, than of any other taſte; tho' its ſweetneſs be of a peculiar kind: and this is the only inſtance, I remember hitherto to have met with of ſalts, which compoſe a ſubſtance really ſweet. Farther, tho' its odour be not ſtrong or offenſive, yet if it be urged with heat enough to evaporate it haſtily, it emits a ſtench, more inſupportable than that of *Aqua fortis*; yet, when theſe fumes ſettle again into a ſalt, their odour will again prove mild, and inoffenſive, if not pleaſant. Thirdly, tho' all the known volatile, acid, and lixiviate ſalts, may be deſtroy'd by one another; as ſpirit of urine mixed with ſpirit of ſalt, or *Aqua fortis*, will make great ebullition, and loſe its peculiar taſte, and ſeveral of its other qualities; and as ſalt of tartar, and other alkalies, will be deſtroy'd, with ebullition,

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lution, by *Aqua fortis*, ſpirit of ſalt, or almoſt any other ſtrong ſpirit of that family; and tho' ſpirit of ſalt, and *Aqua fortis* will be deſtroy'd, both by animal volatile ſalts, and by the fixed ſalts of vegetables: yet our ſalt ſeems above being thus wrought upon by any of the three; and is the only body I know, which would not fret, either with oil of tartar *per deliquium*, ſpirit of ſal-armoniac, ſtrong ſpirit of ſalt, or oil of vitriol. But this is not the only way I try'd it; for I found, that it would not turn ſyrup of violets either red, as acid ſpirits do, or green, as both fixed and volatile ſalts will; nor would the ſtrongeſt ſolution of it change a clear one of ſublimate in common water, either white, as ſpirit of urine, ſal-armoniac, or others of the ſame family; or into an orange tawney, like ſalt of tartar, and other alkalies; but left it tranſparent. In conjunction, however, with ſpirit of ſalt, it would turn ſyrup of violets, red; and, with oil of tartar, green: which ſeemed to argue, that tho' our ſolution, as to ſenſe, was exquiſitely united in the ſeveral mixtures, it left them their reſpective natures undeſtroy'd, and retain'd its own: and yet this ſalt is ſo far from being languid, that *Aqua fortis*, and oil of vitriol themſelves, are, in many caſes, unable to make ſolutions, and perform other things like it, as a menſtruum. Laſtly, tho' this ſalt be volatile of itſelf, yet diſſolved in liquors, it will even boil, without ſubliming, before the liquor be almoſt totally drawn off; whereas, the volatile ſalt of urine, blood, harts-horn, *&c.* aſcend, before almoſt any part of the liquor they are diſſolved in. And tho' this be volatile, yet I remember not, that any fixed ſalt will run near ſo ſoon *per deliquium*; but by abſtraction of the adventitious moiſture, it is eaſily reſtored to its ſaline form; nevertheleſs, it differs from ſalt of tartar, not only in fixedneſs, taſte, and other qualities; but, alſo, in this, that whereas ſalt of tartar requires a vehement fire to flux it, a more gentle heat, than one would eaſily imagine, will melt our ſalt into a limpid liquor. And, whereas ſpirit of wine will diſſolve ſome bodies, and water many, which ſpirit of wine cannot, and oils will diſſolve ſome, for which neither of the other liquors are fit; our ſalt readily diſſolves both in fair water, in the higheſt rectified ſpirit of wine, and in chymical oils themſelves.

A tranſmutation wrought upon ſaline bodies ſuppoſed almoſt indeſtructible.

5. Our next experiment will ſhew what great changes may be effected by the receſs of ſome particles, the acceſs of others, and the new texture of the reſidue, even in inanimate, and ſcarce corruptible bodies. Take one part of good ſea-ſalt, well dried and powdered, and put to it double its weight of good *Aqua fortis*, or ſpirit of nitre; then having kept it for ſome time in digeſtion, diſtil it with a ſlow fire in a retort, till the remaining matter be quite dry, and no more; for the ſubſtance, that will remain in the bottom of the glaſs, is the thing ſought for.

As to the changes hereby effected, we may firſt take notice, that the liquor, which came over, was no longer an *Aqua fortis* or ſpirit of nitre, but an *Aqua regis*. 2. The taſte of the remaining ſubſtance comes, by this operation, to be very much altered; for it retains not that ſtrong ſaltneſs it had before, but is far milder. 3. Whereas common ſalt is a body of very difficult fuſion, our factitious ſalt imitates ſalt-petre in being very fuſible, and will,

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PHYSICS. like that, ſoon melt, by being held in the flame of a candle. 4. But a more conſiderable phenomenon is, that, tho' ſea-ſalt very much reſiſts the fire; and tho' the acid ſpirits of ſalt, vitriol, nitre, vinegar, *&c.* are not only uninflammable themſelves, but hinderers of inflammation in other bodies; yet ſmall lumps of this ſubſtance, caſt upon quick coals, burnt away with a large and vehement flame: and, upon farther trial, having melted a conſiderable quantity of this tranſmuted ſea-ſalt in a crucible; by caſting upon it little fragments of well-kindled charcoal, it would, like nitre, preſently blaze bright. Nor were all its inflammable parts conſumed at one deflagration; for by caſting in more fragments of well-kindled coal, the matter would puff, and flame afreſh, for ſeveral times, according to the quantity which had been put into the crucible. 5. This ſuggeſted a hint of turning an acid ſalt into an alkali, which ſeems to be one of the greateſt changes, that can be attempted, by reaſon of the vaſt difference there is between them in abundance of reſpects. Accordingly, having caſt in ſeveral bits of well-kindled coal, and excited in the melted maſs of our tranſmuted ſalt, as many deflagrations as I could; and then giving it a ſtrong fire, to drive away the reſt of the more fugitive parts, I found it to taſte, not like ſea-ſalt, but fiery upon the tongue, and to have a lixiviate reliſh. I found too, that it would turn ſyrup of violets greeniſh; that it would precipitate a limpid ſolution of ſublimate, made in fair water, into an orage-tawny powder; that it would, like other fixed ſalts, produce an ebullition with acid ſpirits, and even with ſpirit of ſalt itſelf, and con-coagulate with them. I, indeed, conſider'd at firſt, that this new alkali might proceed from the aſhes of the injected coals: but when I reflected too, that a pound of charcoal, burnt to aſhes, yield ſo very little ſalt, that the injected fragments of coal, quite burnt out in this operation, would ſcarce have afforded two or three grains of ſalt; I concluded, that ſo conſiderable a proportion of aſhes, in the whole maſs, could not exhibit all the phenomena of an alkali. And, for farther confirmation, I poured upon a quantity of this lixiviate ſalt, a due proportion of *Aqua fortis*, till the hiſſing and ebullition ceaſed; and then leaving the fluid mixture to coagulate, which it did very ſlowly, I found it, at length, to ſhoot into ſaline cryſtals, which tho' not of the figure of nitre, yet, by their inflammability and magnitude, ſufficiently argued, that there had been a conjunction made betwixt the nitrous ſpirit, and a conſiderable proportion of alkali. I conſider'd, alſo, it might be ſaid, that in our experiment, the nitrous corpuſcles of the *Aqua fortis*, lodging themſelves in the little ſpaces deſerted by the ſaline corpuſcles of the ſea-ſalt, that paſſed over into the receiver, had afforded this alkali; as common ſalt-petre, being treated in ſuch a manner, would leave in the crucible a fixed or alkalizate ſalt: but, as the ſea-ſalt, which was not driven over in ſo mild a diſtillation, and ſeemed a much greater part than that which had paſſed over, was far from being of an alkalizate nature; ſo the nitrous corpuſcles, preſumed to have ſtaid behind, were, whilſt they compoſed the ſpirit of nitre, of an highly volatile, and acid nature, and, conſequently, directly oppoſite to that of alkalies; and if, by the addition of any other ſubſtance,

no

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no more an alkali than ſea-ſalt, an alkali could be obtained out of ſpirit of nitre or *Aqua fortis*, the producibleneſs of an alkali out of bodies of another nature, might be rightly thence inferred; ſo that two ſubſtances, formerly acid, are here turned into one, manifeſtly of an alkalizate nature. But, farther, to proſecute the experiment, by inverting it, we drew two parts of ſtrong ſpirit of ſalt from one of purified nitre; but did not obſerve the remaining body to be any thing near ſo conſiderably changed as the ſea-ſalt, from which we had drawn the ſpirit of nitre; ſince, tho' the ſpirit of ſalt, which came over, brought ſo many of the corpuſcles of the nitre with it, that being heated, it would readily diſſolve leaf-gold; yet the ſalt that remained in the retort, being put upon quick coals, flaſh'd away with a vehement, and flatulent flame, very like that of common nitre. PHYSICS.

6. In attemping to make and improve the *Sal mirabile* of *Glauber*, I drew off from a ſolution of nitre, and oil of vitriol, a good *Spiritus nitri*; which, even before rectification, would diſſolve ſilver, tho' it were diluted with as much common water, wherein ſalt-petre had been diſſolved, as amounted, at leaſt, to double or treble the weight of the nitrous parts: the remaining matter being kept in the fire, till it was dry, afforded a ſalt eaſily reducible, by ſolution in fair water, and coagulation, into cryſtalline grains, of a nature very different both from crude and fixed nitre, and from oil of vitriol. Beſides, theſe cryſtals would not flow in the air, like fixed nitre, and were eaſily fuſible by heat; whilſt fixed nitre uſually requires a vehement fire to fuſe it: and tho' crude ſalt-petre, alſo, melts eaſily; yet, to ſee how different a ſubſtance this of ours was from that, we caſt quick coals into the crucible, without being at all able to kindle it. And when, for farther trial, we threw in ſome ſulphur, alſo, tho' that flam'd away itſelf, yet it did not ſeem to kindle the ſalt, which was hot enough for that purpoſe; much leſs did it flaſh, as ſulphur uſually makes ſalt-petre do. To all which we may add, that a parcel of this white ſubſtance, being, without brimſtone, made to flow for a while in a crucible, with a piece of charcoal, for it to work upon, it became ſtrongly ſcented of ſulphur, and acquired an alkalizate taſte; ſo that it ſeemed almoſt a coal of fire upon the tongue, when licked, before it imbibed any of the air's moiſture; and obtained, alſo, a very red colour: which re-called to my mind, that *Glauber* mentions ſuch a change obſervable in his ſalt made of common ſalt; upon which account, he calls ſuch a ſubſtance his *Carbunculus*. *Phenomena in the proceſs of* Glauber's Sal mirabile.

Here we may, firſt, take notice of the power of mixture, in altering the nature and qualities of the compounding bodies. For, in this caſe, tho' ſea-ſalt requires a naked fire to elevate it; yet the ſaline corpuſcles are diſtill'd over in a moderate heat of ſand; whilſt the oil of vitriol, by whoſe intervention, they acquire this volatility, tho' it be not a groſs corporeal ſalt, but a liquor, which hath been already diſtill'd, is, by the ſame operation, ſo fixed, as to ſtay behind. Nor is the oil of vitriol, only, thus far fixed, but otherwiſe, alſo, no leſs changed: for, when the remaining ſalt has been expoſed to a competent heat, that it may be very dry and white, you ſhall obtain a ſubſtance, not at all taſting of ſea-ſalt, or having the pungency

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PHYSICS. gency or acidity of oil of vitriol. A ſecond particular, here remarkable, confirms what I formerly intimated, that, notwithſtanding the regular and exquiſite figures of ſome ſalts, they may, by the addition of other bodies, be brought to conſtitute cryſtals of very differing, yet curious ſhapes. For if you diſſolve this *Caput mortuum* of ſea-ſealt, in a ſufficient quantity of fair water, and having filtrated the ſolution, ſuffer the diſſolved body leiſurely to coagulate; you will obtain cryſtals of a far greater tranſparency, than the cubes into which ſea-ſalt ſhoots, and of a ſhape far differing from theirs, tho', often, no leſs curious than that of thoſe cubes: and, what is very remarkable, I have often obſerved, thoſe finely-figured cryſtals to differ as much in ſhape from one another, as from the grains of common ſalt. And, indeed, I muſt own, that, whether we impute it to the peculiar nature of ſea-ſalt, or to the great diſparities to be met with in liquors, that paſs for oil of vitriol, my attempts to make the beſt ſort of *Sal mirabile*, have been ſubject to ſo much uncertainty, that I reckon this experiment amongſt ſuch as are contingent.

The tranſmutability of metals proved experimentally, by converting gold into ſilver.

7. The following experiment, ſuppoſes metals, as well as other bodies, to be made of one univerſal matter, common to them all; and to differ but in the ſhape, ſize, motion or reſt, and texture of the ſmall parts they conſiſt of; whence the qualities, which diverſify particular bodies, reſult; and, conſequently, there is no impoſſibility in the nature of the thing, that one kind of metal ſhould be tranſmuted into another.

Having firſt ſuppoſed this, I farther conſidered, that a certain menſtruum, which, according to the doctrine of vulgar chymiſts, is a worthleſs liquor, muſt, according to my apprehenſion, have an extraordinary virtue with regard to gold; I mean, not only to diſſolve, and, otherwiſe, alter it, but to injure the very texture of that metal. To this purpoſe, I made a menſtruum to diſſolve gold, by pouring on the rectified oil of butter of antimony, as much ſtrong ſpirit of nitre, as would ſerve to precipitate out of it all the *Bezoarticum minerale*; and then with a ſmart fire, diſtilling off all the liquor, which would come over, and cohobating it upon the antimonial powder: for tho' ſeveral chymiſts throw this liquor away, upon preſumption, that the ingredients have, in the ebullition deſtroy'd each other; yet experience hath made me prize it, and give it the name of *Menſtruum peracutum*. Having provided a ſufficient ſtock of this liquor, we took a quantity of the beſt gold, and melted it with three or four times its weight of copper; this mixture we put into good *Aqua fortis*, or ſpirit of nitre, that, all the copper being diſſolved, the gold might be left pure, and finely powdered, at the bottom. After the metal had, in this beſt manner, been moſt highly refined, and brought to its uſual luſtre by heat, we put to it a large proportion of the *Menſtruum peracutum*, wherein it diſſolves ſlowly and quietly; and there remained at the bottom of the glaſs, a conſiderable quantity of white powder, that the menſtruum would not touch, and which we found, alſo, as indiſſoluble in *Aqua regia*. The ſolution of gold being abſtracted, and the gold again reduced into a body, yielded, upon a ſecond ſolution, more of the white powder, but not ſo much as at the firſt. Now having ſome little quantity of this powder, it was eaſy, with borax,

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borax, or ſome other convenient flux, to melt it down into a metal, which PHYSICS. metal we found to be white like ſilver, and yielding to the hammer: and ſome of it being diſſolved in *Aqua fortis*, or ſpirit of nitre, confirm'd us, by the odious bitterneſs it produced, in our expectation to find it true ſilver. I was farther confirm'd herein, firſt, by finding, that with ſome other menſtrua, and even with good *Aqua regis* itſelf, I could obtain, from the very beſt gold, diſſolved in them, ſome little quantity of ſuch a white powder; but in ſo very ſmall a proportion to the diſſolved gold, that I never had enough of it, at once, to make me think it worth proſecuting ſuch trials. Secondly, by the experience of a judicious perſon, who had, by diſſolving gold in a certain kind of *Aqua regis*, and, after, by bringing it into a body, rediſſolving it, and repeating this operation very often, reduced a very great part of an ounce of gold into ſuch a white powder. And a third confirmation, I had from ſome trials purpoſely made, wherein this *Menſtruum peracutum* had greater effects upon gold, than by moſt men, and even critics in chymiſtry, have been thought feaſible. Hence, there appears no greater cauſe to doubt, that the abovementioned ſilver was really obtained out of the pure gold, than this, that men have hitherto ſo often in vain attempted to make a real tranſmutation of metals, and to deſtroy the moſt fixed and compact body of gold; the one of which is looked upon as an impracticable thing, and the other as an indeſtructible metal.

If, therefore, we have not impoſed upon ourſelves, this experiment, which yet we once repeated, may afford ſome reflexions of moment. And, firſt, it ſeems from hence probable, that however irrationally the chymiſts talk of a *Tinctura auri* and *Anima auri*, yet ſome ſuch thing may, with due reſtriction, be admitted; for ſome of the more noble corpuſcles, which qualify gold to look yellow, to reſiſt *Aqua fortis*, and to exhibit thoſe other curious phenomena, which diſcriminate it from ſilver, may, either have their texture deſtroy'd by a very piercing menſtruum; or, by a greater congruity with its corpuſcles, than with thoſe of the remaining part of the gold, may ſtick cloſer to the former; and, by their means, be extricated, and drawn away from the latter. Thus, when the corpuſcles of ſulphur and mercury, by a ſtrict coalition, aſſociate themſelves into the body we call vermilion; tho' theſe will riſe together in ſubliming veſſels, and act, in many caſes, as one phyſical body; yet, when exquiſitely mixed with a due proportion of ſalt of tartar, the parts of the alkali aſſociate themſelves more ſtrictly with thoſe of the ſulphur, than theſe were before aſſociated with thoſe of the mercury; whence there will be obtained out of a cinnabar, intenſely red, a real mercury, in appearance, like to fluid ſilver. So that, as our menſtruum may, probably, have a particular operation upon ſome tinging parts of the gold, it is not impoſſible, the yellowneſs of that metal ſhould proceed, not from any particular corpuſcles of that colour, but from the texture; as in the cinnabar, which was highly red, tho' the mercury it conſiſted of, was ſilver-coloured, and the ſulphur but a pale yellow: and, conſequently, the whiteneſs, and other changes, produced in the new metal we obtained, may be attributed, not to the extraction of any tinging particles, but to a change of texture, whereon

PHYSICS. whereon depended the colour, as well as other properties of the gold. And this ſuggeſtion is ſupported, by what hath been, often, aſſured me, that a perſon in the *Netherlands*, grew rich, by extracting a blue tincture out of copper, with a peculiar clear menſtruum, of a weak taſte, after it had been firſt diſſolved in common *Aqua fortis*; ſo as to leave the body white, and reducible by fuſion into a metal of the ſame colour: which I the leſs wonder at, becauſe *Agricola*, mentions the making of a white and malleable copper, in large quantities, upon his own knowledge; and I have myſelf, with pleaſure, made the experiment. Secondly, tho' gold is, generally, ſuppoſed too fixed and permanent a body, to be changeable by art; yet it is not abſolutely indeſtructible thereby: ſince, being acknowledged an homogeneous metal, a part of it was, by our experiment, really changed into a body, which was either true ſilver, or, at leaſt, a new kind of metal, very different from gold. And, ſince it is generally confeſſed, that no body has its form more ſtrictly united to its matter, than gold; and ſince this white powder was produced out of it, only by a corroſive liquor, without violence of fire; it ſeems highly probable, that there is not any body, of ſo conſtant and durable a nature, but that its texture, and, conſequently, its nature may be really deſtroy'd by ſome powerful agent, in due manner applied to it. And, laſtly, it ſeems deducible, from the whole, that there may be a real tranſmutation of one metal into another, made by factitious agents, in a ſhort time, and after a mechanical manner. I ſpeak not here of projection, whereby one part of an aurific powder, is ſaid to turn many hundred or thouſand parts of an ignobler metal into ſilver or gold; becauſe, tho' projection includes tranſmutation, yet tranſmutation is not the ſame with projection, but far eaſier. It ſuffices that we are here taught, that amongſt inanimate bodies, the moſt noble and conſtant ſort of forms, are but peculiar contrivances of the matter, and may, by locally moving the parts, and changing their ſizes, ſhape, or texture, be generated and deſtroy'd; ſince we ſee, that in the ſame parcel of metalline matter, which a little before was true and pure gold; by having ſome few of its parts withdrawn, and the reſt tranſpoſed, or otherwiſe altered in ſtructure, or by both, the form of gold, or that peculiar modification which made it yellow, indiſſoluble in *Aqua fortis*, &c. is aboliſhed; whilſt, from the new texture of the ſame matter, there ariſes that new form, or convention of accidents, from which we call a metal ſilver. And ſince ours was not only diſſoluble in *Aqua fortis*, but manifeſted that exceſſively bitter taſte, which is peculiar to ſilver; there is no neceſſity for a diſtinct agent, or a particular action of a ſubſtantial form, to produce, in a natural body, the moſt peculiar and diſcriminating properties. For it was the ſame menſtruum, devoid of bitterneſs, that by deſtroying the texture of gold, changed it into another, upon whoſe account it acquired, at once, whiteneſs of colour, diſſolubleneſs in *Aqua fortis*, an aptneſs to compoſe a bitter body with it, and many other new qualities. It may, indeed, be readily objected, that it is no very thrifty tranſmutation, to degrade gold to the condition of ſilver: but a tranſmutation is never the leſs real, for not being gainful; and it is no ſmall matter to remove the bounds,

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bounds, which nature ſeems very induſtriouſly to have ſet to the alterations of bodies; eſpecially amongſt thoſe durable, and, almoſt, immortal kinds, in whoſe conſtancy to their firſt forms, ſhe appears to have affected to ſhew herſelf invincible by art. PHYSICS.

But farther to demonſtrate the efficacy of our *Menſtruum peracutum*, we took the fineſt gold that could be procured, and having either granulated, or brought it into plates, diſſolved it in a moderate heat, with a ſufficient quantity of the menſtruum; and having carefully decanted the ſolution into a retort, we very gently, in a ſand furnace, diſtill'd off the liquor: and if we had a mind to elevate more gold, we either poured back upon the remaining ſubſtance the ſame menſtruum, or diſſolved it again with freſh. The liquor being abſtracted, we urged the remaining matter by degrees of fire; and in no ſtronger an one, than may eaſily be given in a ſand-furnace, a conſiderable quantity of the gold would be elevated to the upper part of the retort; and either fall down, in a golden-coloured liquor, into the receiver, or faſten itſelf to the top and neck, in the form of a yellow and reddiſh ſublimate: and ſometimes we had the neck of the retort enriched with numerous large thin red cryſtals, very like rubies, and glorious to behold, which would run in the air *per deliquium*. Nor can I ſee any cauſe to doubt, that, by the re-affuſions of freſh menſtruum upon the dry calx of gold, which remains behind, the whole body of the metal may be eaſily made to paſs through the retort; tho' I forbore to proſecute the experiment ſo far. *Gold render'd volatile.*

It may here be neceſſary to give a caution, that tho' chymiſts think it a ſufficient proof of a true tincture, that the colour of the concrete will not be ſeparated in diſtillation, but the extracted liquor paſs over tinged into the receiver; yet this ſuppoſition may, in ſome caſes, deceive them. And, farther, whereas the particles of ſolid and conſiſtent bodies, are not, always, unfit to help to compoſe fluids, I ſhall venture to add, that even a liquor, made by diſtillation, may, in part, conſiſt of corpuſcles of the moſt compact and ponderous bodies in the world. To manifeſt this, as well as, that ſome bodies are of ſo durable a texture, that their minute parts will retain their own nature, notwithſtanding variety of diſguizes, which may impoſe even upon chymiſts themſelves; I dropped into the yellow liquor, afforded me by the elevated gold, a quantity of clean running mercury, which was immediately tinged with a gold-colour'd film; and ſhaking it about, till the menſtruum would gild no more, I decanted the clarified liquor; and mixing the remaining amalgam of gold and mercury with ſeveral times its weight of borax, I by fuſion eaſily recover'd the ſcatter'd particles of the metal into one little maſs of yellow gold. And whenſoever mention is made of a volatile gold, as it is ſaid to be in ſome minerals, it may be admitted with this explanation, that in our experiment, after abſtraction of the menſtruum, the remaining body being true gold, and, conſequently, in it own nature fixed; yet it is ſo ſtrictly aſſociated with ſome volatile ſaline particles, that theſe being preſſed by the fire, carry up along with them the corpuſcles of the gold, which may be reduced into a maſs by the admixture of borax, or ſome other.

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PHYSICS. other body, fitted to divorce the corpuſcles of the metal from thoſe that would elevate them, and to unite them into grains, too big and ponderous to be ſublimed: thus, in ſome mineral bodies, there may be numberleſs corpuſcles of gold, ſo minute, and ſo blended with the unfixed particles, that they will be carried up together with them by that vehement heat uſually employ'd to bring ores, and metalline maſſes, to fuſion. Yet it is not impoſſible, that theſe corpuſcles of gold, which, in ordinary fuſions, fly away, may be retained, and recovered by ſome ſuch proper addition, as may either work upon, and mortify the other parts of the maſs, without doing ſo to the gold; or by aſſociating with the volatile, and ignobler minerals, prevent their carrying away the gold with them, as they otherwiſe might; or, by its fixedneſs, and ſimilitude of nature, make the diſperſed gold embody with it. Thus, I remember, that ſome good gold, having, for a certain trial, been cupel'd with a great deal of lead, inſtead of being advanced in colour, as in goodneſs, was grown manifeſtly paler than before; whence I conjectured, that ſo great a proportion of lead, might contain ſeveral particles of volatile ſilver; which, meeting with the fixed body of the gold, by incorporating therewith, might be detained: and I was confirmed herein, by finding, upon enquiry, that the gold, inſtead of loſing its weight, had conſiderably increaſed it.

Taſtes varied by mechanical alterations in bodies.

8. We took an ounce of refined ſilver, and, having diſſolv'd it in *Aqua fortis*, ſuffered it to ſhoot into cryſtals; which, being dried, we found to exceed the weight of the ſilver, by ſeveral drams, gain'd by the con-coagulation of the acid ſalts, that had diſſolved, and were united to the metal. Theſe cryſtals we put into a retort, and diſtill'd them in ſand, with, almoſt, as great a heat as we could give in an iron-furnace: but there came over only a very little ſouriſh phlegm, of an ill ſcent; wherefore, the ſame retort being ſuffered to cool, and being then coated, it was removed to another furnace, capable of giving a far greater degree of heat; and, in this, the diſtillation was purſued with ſeveral degrees of fire, till the retort became red-hot, and long continued ſo: but tho', even by this operation, there was very little driven over; yet it ſufficiently manifeſted, that a body extremely bitter, might afford numerous parts not at all bitter, but eminently ſour. For our receiver being taken off, even when cold, the contained ſpirit ſmoked like rectified *Aqua fortis*; and not only ſmelt and taſted like it, but being poured upon filings of crude copper, immediately corroded them, and, in a trice, produced a bluiſh colour, like what that metal gives in good *Aqua fortis*. Afterwards, we made a ſolution with minium and *Aqua fortis*, which being filtred, and evaporated, left a *Saccharum Saturni*, much like the common, made with ſpirit of vinegar: then taking this ſweet vitriol of lead, we endeavoured, in a ſand-furnace, to drive it over; but finding that degree of heat inſufficient, we cauſed the retort to be coated, and transferred it to the other furnace; where, being urged with a naked fire, it afforded ſomewhat more ſpirit than the ſilver had done. This ſpirit ſmoked in the cold receiver, as the other; and, like it, ſmelt of *Aqua fortis*, and was ſo far from retaining any of the ſweetneſs of the concrete which yielded

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yielded it, that it was offensively acid; and being poured upon minium, work'd upon it with noise and bubbles, and quickly afforded a sweet liquor, from whence might have been obtained a true sugar of lead. It is remarkable, that the concrete, which appeared white before distillation, remained, for the most part, behind in the retort, in the form of a black *Caput mortuum*, which was neither sweet nor sour at all, but seemed rather insipid, and was, indeed, but a calx of lead. PHYSICS.

In this experiment, it may be observed, that tho' silver be a body so fixed in the fire, as to endure the cupel itself; and, tho' in the dry'd crystals of silver, the salt, that adheres to the metal, increases its weight but about a third or fourth part; yet this small proportion of saline corpuscles was able to carry up so much of that fixed body, that the inside of the retort was, to a great height, cover'd over with the metalline corpuscles. But the phenomenon which I chiefly take notice of, is, that not only *Aqua fortis*, being con-coagulated with different bodies, may produce very different concretes; but the same numerical saline corpuscles, which, being associated with those of a metal, had already produced a body, eminent in one taste, may, afterwards, being freed from that body, compose a liquor, remarkable for a very different taste; and after that too, being combined with the particles of another metal, with them, constitute a body of a very eminent taste, directly opposite to both the other; and yet these saline corpuscles, if instead of this second metal, they should be associated with such an one, as that they are driven from, would therewith again exhibit the first taste. To prove all this, we took crystals of refined silver made with *Aqua fortis*, and tho' these crystals are excessive bitter; yet having, by a naked fire, extorted from them what spirit we could, and found it extremely acid, we put one part of it upon a few filings of silver, of which it readily made a solution more bitter than gall; and the other part of the distill'd liquor we poured upon minium; when, tho', whilst it was an ingredient of the crystals of silver, committed to distillation, it did, with that metal, compose an intolerably bitter substance; yet the same particles, being loosened from that metal, and associated with those of the lead, with them constituted a solution, which, by evaporation, afforded a *Saccharum Saturni*, sweet as sugar. For farther confirmation, we varied the experiment; and having, in a naked fire, distill'd some dry'd *Saccharum Saturni*, made with *Aqua fortis*, the little liquor which came over, in proportion to the body that afforded it, was so strong a spirit of nitre, that for several hours the receiver was filled with red fumes; and tho' the smoking liquor was vastly sharp, yet part of it being poured upon a piece of its own *Caput mortuum* (in which we perceived no taste) at length exhibited some little grains of a saccharine vitriol; but the other part, being put to filings of silver, immediately fell upon them, with noise and smoke, and soon after, con-coagulated with part thereof, into a salt excessively bitter.

9. Having put a considerable quantity of distill'd rain-water into a clean glass-body, and fitted it with a head, and receiver, I suffer'd it to stand in a digestive furnace, till, by the gentle heat thereof, the water was totally *Water transmuted into earth.*

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PHYSICS. tally abſtracted, and the veſſel left dry; when being taken out of the ſand, I found the bottom of the glaſs wholly covered with a whitiſh ſubſtance, which being ſcraped off with a knife, appeared to be a fine earth, without any manifeſt taſte. This encouraged me to diſtil the rain-water again in the ſame glaſs-body, in the bottom whereof, when the water was all drawn off, lay more of the like earth, which confirmed my conjecture, that the earthy powder might be a tranſmutation of ſome parts of the water into that ſubſtance. Herein, alſo, I was farther encouraged by a phyſician, who aſſured me, that he had frequently found ſuch a white earth in rain-water, after diſtilling the ſame many times ſucceſſively; adding, he found no cauſe to ſuſpect, that if he had continued to re-diſtil the ſame portion of water, it would have yielded him more earth. But the oddneſs of the experiment ſtill ſteeping me in ſuſpenſe, a very ingenious perſon, who had try'd various experiments upon rain-water, gave me ſuch an account of his proceedings, as left me but little ſcruple about this tranſmutation: for, he ſolemnly affirmed, on experience, that rain-water, even after diſtillation in very clean glaſſes, near two hundred times, afforded him this white earth, and that more conſpicuouſly in the latter diſtillation, than in the former. And in comparing this powder with what I made myſelf, I found an agreement between them. And, (1.) Being placed in an excellent microſcope, and expoſed ſo that the ſun-beams might fall thereon, it appeared a white meal, or an heap of corpuſcles exceeding ſmall; and their extreme ſmallneſs was more ſenſibly diſcerned by adding ſome grains of ſand thereto, which made a mixture that looked like that of pebble-ſtones, and the fineſt flower. For our earth, even in the microſcope, appeared to conſiſt of as ſmall particles, as the fineſt hair powder, to the naked eye. Nor could we diſcern this duſt to be tranſparent, tho' when the ſun ſhone thereon, it appeared to have ſome particles a little glittering. (2.) I found, that our powder being caſt into water, would, for a time, ſomewhat whiten it; but when it was once ſettled at the bottom, it continued there undiſſolved, for ſome days, as earth would have done. (3.) Having weighed a quantity, and put it into a new clean crucible, with another inverted over it, I placed it among quick coals, and there kept the crucible red-hot for ſome time, cauſing the fire, afterwards, to be raiſed; but taking out the powder, I neither found it melted, clotted, nor much waſted, beſides what ſtuck to the ſides of the crucible, and to a little clay, wherewith I had luted on the cover. And when I, afterwards, kept this powder in an open crucible amongſt glowing coals, I could not perceive it at all to ſmoke; and having put a little upon a quick coal, it remained fixed, which ſome bodies will not, that yet endure the fire in a red-hot crucible. (4.) I found this powder to be much heavier in ſpecie than water: for employing a nice pair of ſcales, it balanced ſomewhat more than twice its bulk of common water. I, farther, took ſome wood-aſhes, which I had cauſed to be boiled three or four times in a plentiful proportion of water, to free them from ſalt; and having put them, very dry, into common water, found them but little heavier than our powder; ſurpaſſing in weight, water of the ſame bulk but twice, and a little more than a ſixth part. We may add, that glaſs, which is a very compact

body,

body, is but little, if at all, more than twice and a half as heavy as water of equal bulk; ſo that the gravity of this powder, being added to its fixedneſs, and other qualities, juſtly entitles it to the diſtinction of earth. My learned friend, before-mentioned, hath procured of it near three quarters of an ounce from one ounce of water.

Theſe ſeveral relations, in a very ſingular manner ſupport the corpuſcular principles. For, if the elements themſelves are tranſmutable, and thoſe ſimple and primitive bodies, which nature is preſumed to have intended ſtable and permanent ingredients of the bodies ſhe compounds, may by art be deſtroy'd, and re-produced; why may not the changes, which happen in other bodies, proceed from the local motion of the minute or inſenſible parts of matter, and the changes of texture conſequent thereto? Some atomiſts would here be determining, by what particular ways this ſtrange tranſmutation of water into earth may be performed; and, particularly, tell how the continual, but ſlowly agitated parts of water, by their innumerable occurſions, may, by degrees, rub themſelves into ſuch ſurfaces, as either to ſtick very cloſe to one another by immediate contact, or entangle themſelves into cluſters of coherent particles, too heavy to be ſupported by the water. But tho' many things in favour of ſuch conjectures, may hence be urged; yet the full diſquiſition of ſo difficult a ſubject, is too long and intricate to be proper for this place. And, therefore, we will, for a while, ſuppoſe this tranſmutation real; and conſider, whether it doth not much diſcredit ſome of the chief doctrines of the chymiſts, and a fundamental one of *Helmont*. For if the pureſt water may be turned into earth, it will be eaſy to make it probable, that the other ingredients of mixed bodies, which the chymiſts call their hypoſtatical principles, are capable of being tranſmuted into one another. Beſides, if out of the ſimpleſt water, a moderate fire can produce a large proportion of earth, which was not formerly pre-exiſtent in it; how ſhall we be ſure in all the analyſes, which the fire makes of mixed bodies, the ſubſtances thereby exhibited, are obtained by ſeparation only, without any tranſmutation? *Helmont*, we know, makes water to be the material principle of all bodies. But as his grand argument is grounded on his alkaheſt, which, as he affirms, by being digeſted with, and diſtilled from other tangible bodies, reduces them all, at laſt, into a liquor no way different from rain-water; tho' we ſhould grant the fact, yet the experiment of our powder will warrant us to queſtion the concluſion. For if all mixed bodies be therefore, materially from water, becauſe they are, by the operation of a fire and a menſtruum, after having paſſed through ſeveral previous changes, reduced, at length, into inſipid water; by the ſame way of arguing, I might ſay, that all thoſe bodies are materially but diſguized earth, ſince water itſelf may be turned into earth.

But to leave theſe reflexions, I would not not have it thought ſtrange, that whilſt I inſiſt upon the many particulars, which ſeem to evince the change of water into earth, I ſhould intimate a diffidence about it. For I muſt confeſs, that having unluckily loſt a whole paper of the powder I had myſelf made; and having, unexpectedly, been obliged to remove from my furnaces,

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PHYSICS. before I had gone thro' half the trials, I judged requiſite in ſo nice a caſe; I have not yet laid aſide all my ſcruples. For, (1.) I would gladly know, whether the untranſmuted rain-water, by the depoſition of ſo much terreſtrial matter, were grown lighter in ſpecie than before, or ſharp in taſte; and I would, alſo, be ſatisfied, whether inſipid liquors may not work as menſtrua upon ſtones, or earthy bodies: not to queſtion, whether the particles of rain-water may not, by their mutual attrition, or ſome other action upon one another, be reduced into ſhapes and ſizes fit to compoſe ſuch a menſtruum, as the liquor was not before; as in ſeveral plants, which ſeem to be nouriſhed only with water, the ſap is endowed with a ſharp taſte, great penetrancy and activity of parts. (2.) It were alſo fit to know, whether the glaſs-body, wherein all the diſtillations are made, loſes of its weight, any thing near ſo much as the obtained powder amounts to, over and above the decreaſe of weight, which may be imputed to the action of the heat upon the ſubſtance of the glaſs, in caſe it appear by another glaſs, kept empty in an equal heat, and for the ſame time, that the glaſs loſes by ſuch operations any thing conſiderable. And it were, alſo, not impertinent to try, whether the gravity of the obtained powder be the ſame in ſpecie with that of the glaſs, wherein the diſtillations were made. (3.) I could wiſh, likewiſe, that it were more demonſtrably ſhewn, what is, on all hands, taken for granted, that diſtill'd rain-water is a perfectly homogeneous body: for if it be not, many ſuſpicions might be ſuggeſted about its tranſmutation into earth; and if it is, it will be very difficult to conceive, how a perfectly and exquiſitely homogeneous body ſhould, without any addition, or any ſeminal or plaſtic principle, be brought to afford a large quantity of a matter of much greater ſpecific gravity than itſelf; ſince we ſee, that no aggregate, we can make, of bodies, equiponderant in ſpecie with water, by virtue of their convention, grows ſpecifically heavier than it. (4.) Having had the curioſity to try, whether corroſive liquors would operate upon our white powder, I found, that not only good oil of vitriol would corrode it, but ſtrong and dephlegmed ſpirit of ſalt readily work'd upon part of it; and that, without the aſſiſtance of heat, tho' not without hiſſing, and exciting numerous bubbles: yet, when I ſuffered this mixture to ſettle, a very great proportion of the powder remained in the lower part of the liquor, as if that had rather fretted, than diſſolved it. Nor muſt I omit, that ſometimes I have excited ſuch an ebullition, by pouring the ſame liquors upon the earthy part of wood-aſhes, ſeveral times waſhed in boiling water: to which might be added, that ſometimes, alſo, I have thought this powder gritty between my teeth. But whether it be truly earth or not, the alteration is ſo great, and effected in ſo ſimple a way, that it cannot but afford us a conſiderable inſtance, of what the varied texture of the minute parts may perform in a matter confeſſedly ſimilar. And, if frequently diſtill'd rain-water ſhould not be allowed homogeneous, our experiment will excellently ſhew, how little we are bound to believe what the chymiſts, and others, tell us, when they pretend, manifeſtly, to exhibit homogeneous principles, and elementary bodies; and how difficult it is to be

be certain, when a body is absolutely irresoluble into specifically different substances; and, consequently, what is the determinate number of the perfectly simple ingredients of bodies. I will not now mention my attempts to transmute pure alkalizate salts into earth, because I do not yet know, whether the trials will answer my hopes: but upon this subject, I could add something about the changes, which may be wrought upon highly rectified spirit of wine, which would, perchance, make other things of the like kind thought more feasible. For, whereas it is a known thing, that this spirituous liquor being kindled, will, for ought appears, be totally turned into flame; yet I have, without any addition, obtained from such spirit of wine, a considerable quantity of incombustible phlegm. And, by another way, some persons, working by my directions, reduced considerable quantities of high-rectified spirit of wine into a liquor, which was, for the most part phlegm; from which change, it seems deducible, that the same portion of matter, which, by being kindled, would be turned all into fire, may, by another way of management, be turned into water; and this, without the addition of any thing, and without being wrought upon by any visible body, but one so extremely dry, as duly prepared salt of tartar; and that itself is not indispensably necessary, because I, by another way, obtained this phlegm, without employing the salt, or any other visible body whatever.

10. There is one experiment more, with which I design to conclude. Take of good oil of vitriol, and spirit of wine, that will burn all away, equal parts in weight; put them together gradually, and having placed the mixture in a bolt-head or glass-egg, with a long neck, and carefully stopped in with a cork and hard wax, set the vessel, in a moderate heat, to digest for a competent time; then pour out the mixture into a tall glass cucurbite, to which carefully lute on a head and a receiver; and, with a very gentle fire, abstract the spirit of wine, which will first ascend: and when the drops begin to come over fourth, shift the receiver, and continue the distillation with great care, that the matter boil not over; and when about half the acid liquor is come over, change the receiver once more, and continue the distillation; increasing the fire towards the latter end, 'till you have brought over all you can: and what remains in the bottom of the cucurbite must be put into a glass, well stopped to keep it from the air. *Phenomena from the distillation of oil of vitriol with spirit of wine.*

(1.) To the production of most, if not all the phenomena of this experiment, it is not absolutely necessary, that a long digestion be premised, tho' the experiment will succeed the better for it. (2.) I have, sometimes, made use of oil of sulphur *per Campanam*, instead of oil of vitriol; and tho' it succeeded in several particulars, yet I afterwards chose to employ oil of vitriol, both because it, in some points, better answer'd; and, because I would not give occasion to suspect, that the odours, hereafter to be mentioned, as phenomena of our experiment, were owing to the common sulphur, and no way proceeded from the acid salt, wherewith that oil abounds. (3.) I, likewise, digested oil of vitriol with *Spanish* wine, instead of spirit of wine, and, by this means, obtained an odd spirit, and residue, with some other phenomena, which, in regard wine is a liquor of a less simple nature than

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PHYSICS. than its ſpirit, are leſs fit for my preſent purpoſe. (4.) Great care muſt be had in regulating the fire, when once a conſiderable part of the acid ſpirit, mentioned in the proceſs, is come over. For, if the fire be not increaſed, the reſt will ſcarce aſcend: and if it be increaſed a little too much, the matter will be apt to ſwell in the cucurbite, and run over into the receiver.

Now the oil of vitriol, and ſpirit of wine, being both of them diſtilled liquors, drawn from ſimple and familiar ſubſtances, and, conſequently, volatile; one would expect, that they ſhould be brought over united, as I have tried, that the ſpirit of wine, with that of nitre, or of common ſalt, may be; and as the ſpirits of different vegetables are; or, at leaſt, that the diſtillation ſhould not much alter them from what it found them, after they had been well mixed together; yet they exhibited ſeveral conſiderable and ſurprizing phenomena. For, firſt, whereas ſpirit of wine has no great ſcent, nor a good one, and moderately dephlegmed oil of vitriol is inodorous; the ſpirit, which firſt comes over from their mixture, hath a ſcent not only very different from ſpirit of wine, but from all things elſe, that ever I ſmelt. And as this new odour ſeems very fragrant, I have ſometimes had it ſo exceeding ſubtile, that in ſpite of the care which was taken to lute the glaſſes exactly, it would perfume the neighbouring parts of the laboratory, and not, afterwards, be kept in by a cloſe cork, covered with two or three ſeveral bladders, but would ſmell ſtrongly at ſome diſtance from the vial that contain'd it. But, 2. to ſhew how much the odours of bodies depend upon their texture; after this volatile ſpirit is come over, and has been followed by an acid one, it will uſually, towards the latter end of the diſtillation, be ſucceeded by a liquor, that ſmells ſtrongly of brimſtone. 3. There is produced in this operation, a liquor, that will not mix either with the mentioned fragrant, or with the fetid ſpirit, but is very different from both; and ſo very pleaſant, ſubtile, and aromatic, that it recedes as well from ſpirit of wine, as oil of vitriol. 4. When the diſtillation is carried on far enough, you will find at the bottom, that the two ſpirits above-mentioned, (for oil of vitriol is rather a ſaline ſpirit, than an oil) have produced a black ſubſtance, almoſt like pitch or jet. 5. And this ſubſtance, tho' produced by two bodies, which were not only fluid, but diſtill'd, will be both conſiſtent and brittle. 6. Tho' ſpirit of wine be reputed the moſt inflammable, and oil of vitriol the moſt corroſive liquor known; yet I could not find, that this black ſubſtance would eaſily, if at all, be brought to flame or burn; nor that it had any diſcernible taſte, tho' both the liquors, from whoſe mixture it was obtained, are exceeding ſtrong and pungent. 7. Tho' both theſe liquors will mix with common water, I obſerved, that this pitchy maſs would not diſſolve therein for very many hours. And, laſtly, tho' the oil of vitriol, and the ſpirit of wine, were both of them diſtill'd liquors, and one of them exceeding volatile and fugitive; yet the black maſs produced by them, was ſo far fixed, that I could not make it riſe by a conſiderably ſtrong and laſting fire, that would have raiſed a much more ſluggiſh body, than the heavieſt of thoſe, which concurred to produce it.

Now,

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Now, in theſe experiments, it cannot well be pretended, that any ſubſtantial forms are the cauſes of the effects recited: for, beſides, that in the bodies employ'd in moſt of the caſes, the ſeminal virtues, if they had any before, may be ſuppoſed to have been deſtroy'd by the fire; they were ſuch, as thoſe I argue with, would account factitious, being artificially produced by chymical operations. And it is not more manifeſt, that in the production of theſe effects, there happens a local motion, and change of texture, by the operations, than it is precarious, that they are the effects of ſuch things, as the ſchools fancy ſubſtantial forms to be. And, ſince it is in theſe experiments, by the addition of ſome new particles of matter, or the receſs or expulſion of ſome pre-exiſtent ones; or, which is the moſt frequent way, by the tranſpoſition of the minute parts; yet, without excluding the other two; that I have been able to produce, by art, a number of ſuch conſiderable changes of qualities, as are not ordinarily preſented us by nature, where ſhe is preſumed to work by the help of ſubſtantial forms; it is, ſurely, probable, that the ſame univerſal and fertile principles, motion, bulk, ſhape, and texture, of the minute parts of matter, may, under the conduct of nature, ſuffice, likewiſe, to produce thoſe other qualities of natural bodies, of which we have given no particular inſtances. PHYSICS.

SECT. VIII.

Remarks upon particular qualities.

THE term quality, is very ambiguous, and has been applied to ſome things, which ought rather to have been look'd upon as ſtates of matter, or complexions of particular qualities, as animal, health, beauty, *&c.* There are, alſo, other attributes, as ſize, ſhape, motion, and reſt, uſually reckon'd among qualities, which may more conveniently be eſteem'd the primary modes of the parts of matter; ſince from theſe ſimple attributes, all the qualities are derived.

One of the more received diviſions of phyſical qualities, is into manifeſt and occult. We diſtribute the former into firſt, ſecond, and third; to the two laſt of which, we may refer ſeveral qualities not treated of by ſchool-writers of phyſical ſyſtems: and theſe, for diſtinction ſake, might, ſome of them, be ſtyled the chymical qualities of things; becauſe *Ariſtotle* and the ſchool-men, being unacquainted with them, they have been principally introduced by means of chymical operations and experiments: ſuch are fumigation, amalgamation, cupellation, volatilization, precipitation, *&c.* by which operations, among other means, corporeal things come to appear volatile or fixed, ſoluble or inſoluble in ſome menſtrua, amalgamable or unamalgamable, *&c.* which as well deſerve the name of qualities, as ſeveral other attributes, to which it is allow'd. And to theſe chymical qualities, ſome others might be added, which, becauſe of the uſe that phyſicians principally make of them, may be call'd medical; whereby ſome ſubſtances receiv'd into the human body, are reſolving, diſcuſſing, ſuppurating, abſterſive, *&c.* For tho' ſome faculties of medicines, as thoſe of heating, cooling, drying, attenuating, purging, *&c.* may be conveniently referr'd to the firſt, ſe-

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PHYSICS. second, or third qualities, mentioned by naturalists, whilst others are reckon'd occult; and tho' these medical qualities are treated of by physicians; yet as several of them ought not to be referr'd to the qualities whereto they are often ascribed; so the handling of them, may be look'd upon as a desideratum, and well deserves a distinct place, in natural philosophy.

But before I proceed, I think proper to solve three grand scruples, which may possibly arise in our doctrine of qualities. The first of these, proceeds from the opinion of vulgar and *Aristotelian* philosophers, that diversity of qualities must needs flow from substantial forms; either, because it is part of their nature to be the principles of properties, and peculiar operations in the bodies they inform; or else, because several of them, are such as no mixture of the elements is capable of producing.

We have, already, in examining substantial forms, shewn the first of these two suppositions unworthy to be admitted. It, therefore, only remains, that we examine, also, the second supposition; to which, *Sennertus* adds, that, as no bare mixture of the elements, so no general *forma mistionis* is sufficient to account for several qualities, which he enumerates.

But as this difficulty takes it for granted, that there are four elements, from whose various mixtures, all other sublunary bodies arise; whence, they are only solicitous to prove, that particular qualities cannot flow from their mixture; I am not concern'd in their whole discourse, because I admit not the hypothesis of the four elements: yet I may observe from hence, that by the confession of such modern *Peripatetics*, as urge this argument, those, and other *Aristotelians*, were mistaken, who ascrib'd to the mixtures of the elements, effects, for which these maintain them to be insufficient. I shall, however, consider the difficulty itself, not only as it may be propos'd by *Peripatetics*, but by chymists; who, tho' some of them do not allow of the four elements, yet agree, with the schools, that there is a determinate number of ingredients of compounded bodies, from whose mixture and proportion many qualities must be deriv'd; those that cannot, being resolved to flow from a higher principle, whether it be a substantial form, or something for which chymists have several names, tho', I doubt, no settled idea.

But, first, I readily acknowledge, that in some respects, and in some cases, this grand supposition may be well-grounded; but then, I look upon it, rather as a part of the corpuscular doctrine, than an objection against it: for when there happens a strict connexion betwixt the modification of matter, which is requisite to exhibit one phenomenon, and that from which another will necessarily follow; we teach, that he, who, by a change of texture, gives a portion of matter the former modification, likewise qualifies it, by the same change, to exhibit the phenomenon agreeable thereto; tho' one would not, perhaps, suspect them to have any such dependance upon one another. Thus, for instance, strong spirit of distill'd vinegar, by virtue of its being an acid spirit, hath the faculty to turn syrup of violets red; but, if by making with this spirit, a strong solution of coral, you destroy the acidity of the spirit of vinegar; this liquor, as it has quite another taste, so it will have another operation, than formerly, upon the syrup of violets.

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For upon a trial, I purposely made to illustrate this matter, I found, that the solution, just mention'd, and some others, made with spirit of vinegar, would presently, like an alkaline or urinous salt, turn syrup of violets from its native blue, to a lovely green. And prosecuting the experiment, it appear'd, that spirit of salt, dephlegmed by a fit concrete, tho' the solution were vehement strong, had yet the same effect on syrup of violets. Now, things may acquire, by mixture, very different qualities from those of any of the ingredients. Thus sugar of lead is extremely sweet, tho' the minium and the spirit of vinegar, of which it is made, be, the one insipid, and the other sour. And, tho' neither *Aqua regis*, nor crude copper, have any thing in them of blue; yet the solution of this metal in that liquor is of a deep blue: and, sometimes I have had the solution of crude mercury in good *Aqua fortis*, of a rich green; tho' it would not long continue. So that they are much mistaken who imagine, either that no manifest qualities can be produced by mixture, except those that reside in the elements, or result immediately from the combinations of the four first qualities. For it is manifest, that nature and art must continually make mixtures of bodies, both already compounded; as when ashes and sand compose the common coarse glass; or when nature combines sulphur with unripe vitriol, and, perhaps, other substances, in a marcasite; and, also, of bodies already re-compounded; as native vitriol is made in the bowels of the earth of an aqueous liquor impregnated with an acid salt, and of a cupreous or ferruginous mineral, strictly united both to a combustible sulphureous substance, and to another body of a more fixed and terrestrial nature. And thus artificers may easily produce fine new colours, by skilfully mixing in the flame, two pieces of amel of colours more simple than that which results from their colliquation. And this way of combining bodies, not simple or elementary, will be acknowledged more extensive in the production of various qualities, and phenomena of nature, from considering how much the variation of the proportion of the ingredients in a mixed body, may alter the qualities and operations of it; and that this proportion may be varied, almost *in infinitum*. PHYSICS.

I next observe, that it is an ill-grounded hypothesis to suppose, that new qualities cannot be introduced into a mixed body, or those that it had before be destroy'd, unless by adding or taking away a sensible portion of some one or more of the *Aristotelian* elements, or chymical principles. For there may be many changes, as to quality, produced in a body, without visibly adding or taking away any ingredient, barely by altering the texture, or the motion of the minute parts it consists of. When water, hermetically seal'd up in a glass, is, by the cold, turn'd into ice, and thereby both loseth its former fluidity and transparency, and acquires firmness, brittleness, and opacity, which qualities leave it again upon a thaw; I demand, what element, or hypostatical principle can be shewn to get into or out of this seal'd glass, and by its intrusion and recess, produce these alterations in the included body? So in that fixed metal silver, what sensible accession or decrease can be proved to be made, as to ingredients, when, by bare ham-

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PHYSICS. mering, it acquires a brittleneſs, which, by heating in the fire, wherein it ſenſibly loſes nothing, it may preſently be made to exchange for its former malleableneſs: and the ſame experiment, alſo, ſhews, that the inviſible agitation of the parts may alone ſuffice to give a body, at leaſt for a while, new qualities; ſince a thick piece of ſilver briſkly hammer'd, will quickly acquire a conſiderable degree of heat, whereby it will be enabled to melt ſome bodies, to dry others, and to exhibit various phenomena, that it could not produce when cold. I might add, that ſpirit of nitre, tho' when included in a well-ſtopp'd vial, in the form of a liquor, it appears tranſparent, and without redneſs, will yet fill the upper part of the vial with red fumes, if the warm ſun-beams, or any fit heat, put the nitrous ſpirits into a briſker motion than they had whilſt in the form of a liquor. I might, alſo, demand what new element, or principle, is added to a needle, when the bare approach of a vigorous load-ſtone, endows it with thoſe admirable qualities of reſpecting the poles, and drawing other needles to it; and what ingredient the ſteel loſes, when by a contrary motion of the load-ſtone, it is, in a minute, deprived of its magnetiſm.

In the third place, it muſt be remember'd, as we formerly obſerved, that when we conſider how numerous and various phenomena may be exhibited by mixed bodies, we are not preciſely to look upon them as portions of matter of a determinate nature or texture, but as they are parts of our ſyſtem, and, conſequently, placed among other bodies. For being hereby fitted to receive impreſſions from ſome of thoſe bodies, and to make impreſſions upon others, they will, upon this account, be render'd capable of producing, either as principal or auxiliary cauſes, a much greater number and variety of phenomena, than they could, if each of them were placed in a medium, that no way contributed to, or hinder'd its operations.

In the laſt place, I aſſert, that the four *Peripatetic* elements, and the three chymical principles, being unable to give a tolerable account of the phenomena of nature, we muſt ſeek for ſome more univerſal principles; and, that thoſe of the corpuſcular philoſophy, have a great advantage in being far more fertile and comprehenſive than they. Such phenomena, as the conſtant and determinate ſhape and figure of the mountains in the moon; the ſtrange generation and periſhing of the ſpots of the ſun, *&c.* cannot be aſcribed to the four elements, or their mixtures; nor to thoſe of the three chymical principles, which are allowed to be confin'd to the ſublunary region. And there are very many phenomena in nature, ſeveral whereof, neither the *Peripatetic*, nor the chymical doctrine about the elements, or the ingredients of bodies, will enable us to ſolve; as the eclipſes of the ſun, the moon, and the ſatellites of *Jupiter*; the proportion of the acceleration of deſcent obſervable in heavy bodies; the ebbing and flowing of the ſea; with a great number of magnetical, muſical, ſtatical, dioptrical, catoptrical, and other ſorts of phenomena.

Having thus ſhewn, that the vulgar doctrine, about the ingredients of bodies, falls very ſhort of ſolving ſeveral kinds of nature's phenomena, it will follow, in general, that it is fit to look out for ſome more pregnant and uni-

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universal principles; and that in particular those of the corpuscular hypothesis are preferable to the vulgar, will appear hereafter. And, indeed, it were strange, if the consideration of the various motions and textures of bodies, should not serve to account for far more appearances, than the bare knowledge of the number of their quiescent ingredients: for as local motion is that which enables natural bodies to act upon one another; so the textures of bodies are the principal things, that both modify the motion of agents, and diversify their effects, according to the various natures of the patient. PHYSICS.

I come now to consider the second, and, indeed, the greatest difficulty objected against our doctrine of the origin of qualities. 'Tis incredible, some will say, that so great a variety of qualities, as we actually find in natural bodies, should spring from principles so few in number as two; and those so simple as matter and local motion; whereof the latter is but one of the six kinds of motion reckon'd up by *Aristotle* and his followers, who call it lation; and the former being all of one uniform nature, is, according to us, diversify'd only by the effects of local motion. To solve this difficulty, I shall shew, first, that the other universal affections of matter, are manifestly deducible from local motion; and next, that these principles being variously associated, are so fruitful, that a vast number of qualities, and other phenomena of nature, may result from them.

Now, supposing, what is evident, (1.) that the local motion belonging to some parts of the universal matter, does not all tend the same way, but has various determinations in the several parts of this matter; it will follow, that by local motion thus circumstanced, matter must be divided into distinct parts, each of which being finite, must necessarily have, (2.) some bulk or size; and, (3.) some determinate shape or other.

And since all the parts of universal matter are not always in motion, some of them being arrested by their mutual implication, or, having communicated all that they had to other bodies; the consequence is, that some of the portions of the common matter will be, (4.) in a state of rest. And these are the most primary and simple affections of matter.

But, because there are some others that flow naturally from these; and are, tho' not altogether universal, yet very general and pregnant; I shall subjoin the most fertile principles of the qualities of bodies, and other phenomena of nature.

Farther then, not only the greater fragments of matter, but the less, which we, therefore, call corpuscles, or particles, have certain local respects to other bodies, and to those situations, which we denominate from the horizon; so that each of these minute fragments may have, (5.) a particular posture or position, as erect, inclining, *&c.* and, with regard to us who behold them, (6.) a certain order, upon account whereof we say, one is before or behind another: and, (7.) many of these fragments being associated into one mass, have a certain manner of existing together, which we call texture, or by a more comprehensive word, modification. (8.) And because there are very few bodies, whose constituent

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PHYSICS. parts can, by reaſon of the irregularity, or difference of their figures, and for other reaſons, touch one another every where ſo exquiſitely as to leave no intervals between them; almoſt all conſiſtent bodies, and thoſe fluid ones, that are made up of groſſer parts, will have pores. But (9) very many bodies having particles, which, by their ſmallneſs, or their looſe adherence to the bigger, or more ſtable parts of the bodies they belong to, are more eaſily agitated, and ſeparated from the reſt, by heat, and other agents; there will be great numbers of bodies which emit thoſe ſubtile emanations, that are commonly called *effluvia*. And as thoſe conventions of the ſimple corpuſcles, that are ſo fitted to adhere to, or be complicated with one another, conſtitute ſuch durable cluſters of particles, as we may call the primary concretions, or elements of things: ſo (10) theſe themſelves may be mixed with one another, and conſtitute compound bodies; and even theſe reſulting bodies may, by being mix'd with other compounds, prove the ingredients of re-compounded bodies; and ſo afford a way, whereby nature varies matter, which we may call mixture, or compoſition; not that the name is here ſo proper, as when applied to the primary concretions of corpuſcles; but becauſe it belongs to a multitude of aſſociations, and ſeems to differ from texture; whereto, perhaps, it is reducible, in this, that always in mixtures, but not in textures, there is required a heterogeneity of the component parts. And every diſtinct portion of matter, whether it be a corpuſcle, a primary concretion, or a body of the firſt, or of any other order of mixt bodies, is to be conſider'd, not as if it were placed *in vacuo*, nor as if it had relation only to the neighbouring bodies; but as being placed in the univerſe, conſtituted as it is, amongſt an innumerable company of other bodies; whereof ſome are near it, and others very remote; ſome are great, and ſome ſmall; ſome particular, and ſome general agents; and all of them govern'd as well (11) by the univerſal fabric of things, as by the laws of motion, eſtabliſhed by the author of nature, in the world.

And having thus enumerated eleven very general affections of matter, which, with itſelf, make up twelve principles of variation in bodies; I may, in behalf of the corpuſcular philoſophy, apply to the origin of qualities, a compariſon of the old atomiſts, uſed by *Lucretius*, and others to illuſtrate the production of an infinite number of bodies, from ſuch ſimple fragments of matter, as they thought their atoms to be. For, ſince of the 24 letters of the alphabet, aſſociated ſeveral ways, all the words of the ſeveral languages of the world may be made; ſo, ſay theſe naturaliſts, by variouſly connecting particular numbers of atoms, of particular ſhapes, ſizes, and motions, into maſſes, an innumerable multitude of different bodies may be formed. Wherefore, if to the four affections of matter, which I call the moſt primary, and ſimple, we add the ſeven other ways, whereby it may be alter'd; we ſhall have eleven principles ſo fruitful, that, from their various aſſociations, may reſult a much vaſter multitude of phenomena; and among them of qualities, than one who does not conſider the thing attentively would imagine. For, ſuppoſing our principles were but as ſo many letters of the alphabet, that could only be put together in different num-

numbers, and in various orders; the combinations, and other associations that might be made thereof, is far more numerous, than a man who knows not how to compute them, could eafily credit, when told.

But farther, each of theſe producers of phenomena, admits of a ſcarce credible variety: for, not to deſcend ſo low as inſenſible corpuſcles, many thouſands of which may be requiſite to conſtitute a grain of muſtard-ſeed; what an innumerable company of different magnitudes may we conceive, between the bulk of a mite, and that of a mountain, or the body of the ſun?

And ſo, tho' figure be one of the moſt ſimple modes of matter; yet it is capable of ſo great a multitude of differences, that it is of them, and their properties, that *Euclid*, *Apollonius*, *Archimedes*, *Theodoſius*, *Clavius*, and later writers, have demoſtrated ſo many propoſitions. And yet, all the regular figures are nothing to ſuch irregular ſhapes as may be met with in nature; moſt of which have no particular appellations, their multitude and variety having kept men even from enumerating them.

I may add, that theſe varieties of figure and ſhape, alſo ſerve to modify the motion, and other affections of the corpuſcles endow'd with them; and of the compound body whereof it makes a part: and that the ſhape and ſize of bodies, whether ſmall or great, may exceedingly diverſify their nature, and operation, is very manifeſt, by conſidering how many different ſorts of tools, and inſtruments, almoſt each of them fit for many different operations and uſes, ſmiths, and other mechanics, have form'd out of pieces of iron, only by making them of different ſizes and ſhapes.

Thus, likewiſe motion, which ſeems ſo ſimple a principle, eſpecially in ſimple bodies, may, even in thoſe, be very much diverſify'd: for it may be more or leſs ſwift, and that in almoſt infinite degrees; it may be ſimple or uncompounded, uniform or irregular, and the greater celerity may precede or follow; the body may move in a ſtreight line, or in a circle, an ellipſis, hyperbola, parabola, *&c.* The motion of a body may be alſo varied, according to the ſituation, or nature of the matter it hits againſt, as that is capable of reflecting or refracting it, or both; and this after ſeveral manners. It may have an undulating motion, and that with ſmaller or greater waves; or it may have a rotation about its own axis, or both a progreſſive motion and a rotation; and the one either equal to the other, or ſwifter than it, in almoſt infinite proportions. As to the determination of motion, the body may move directly upwards, or downwards, declining or horizontally, eaſt, weſt, *&c.* according to the ſituation of the impelling body. And beſides, theſe, and other modifications of the motion of a ſimple corpuſcle, or body, whoſe phenomena, or effects, will be alſo diverſify'd by its bulk and figure; there will happen a new and great variety of phenomena, when ſeveral corpuſcles, tho' primogeneal, and much more if they be compounded, move at once, ſo that the motion is conſider'd in ſeveral bodies: for there will ariſe new diverſifications, from the greater or leſs number of the moving corpuſcles; from their following one another cloſe or at a diſtance; from the order wherein they follow each other; from the uniformity of their motion, or the confuſion of it; from the equality or inequality of their

PHYSICS. their bulk, and the ſimilitude or diſſimilitude of their figures; from the narrowneſs or wideneſs, &c. of the channel or paſſage in which they move; with the thickneſs, thinneſs, pores and the conditions of the medium thro' which they move; from the equal or unequal celerity of their motion, and force of their impulſe: and the effects of all theſe are variable, by the different ſituation and ſtructure of the organs, or other bodies, on which theſe corpuſcles ſtrike.

And ſince local motion is, next to the author of nature, the principal agent in the production of her phenomena, theſe diverſities, in the motion of bodies, muſt neceſſarily produce a ſtrange variety in their nature, and qualities. Thus in muſic, as the inſtrument of producing ſounds trembles more or leſs ſwiftly, it puts the air into a vibrating motion, more or leſs brisk; and produces thoſe diverſities of ſounds, which muſicians have diſtinguiſh'd into notes, and ſubdivided; aſſigning to each a particular name. And tho' the bodies, from whence theſe ſounds proceed, may be of very different natures, as wire, ſtrings, pipes, &c. yet, provided they put the air into the like waving motion, the ſound, and even the note will be the ſame; which ſhews how much that great variety, which may be obſerv'd in ſounds, is the effect of local motion. And if the ſound come from an inſtrument, as a lute, where not only one ſtring hath its proper ſounds, but many have, among them, ſeveral degrees of tenſion, and are differently touch'd, as ſometimes theſe, and ſometimes thoſe together, whereby more or fewer, or none of their vibrations, come to be coincident; they will ſo ſtrike the air, as to produce ſometimes thoſe pleaſing ſounds we call concords, and ſometimes thoſe harſh ones we call diſcords.

Hence, then appears the fertility of our principles. And this great variety may be produced, not only by the diverſifications that each ſingle principle is capable of; but much more by the ſeveral combinations that may be made of them; eſpecially ſince our external and internal ſenſes are ſo conſtituted, that each of thoſe modifications may produce a diſtinct impreſſion on the organ, and a correſpondent perception in the diſcerning faculty: many of which perceptions, eſpecially if diſtinguiſhed by proper names, belong to the liſt of particular qualities.

The third and laſt difficulty that remains to be conſider'd, may be thus propos'd. Since, according to the corpuſcular hypotheſis, not only one or two qualities, but all of them, proceed from the magnitude, ſhape, and contexture of the minute parts of matter; if two bodies agree in one quality, and ſo in the ſtructure on which that quality depends, they ought to agree in other qualities alſo; ſince thoſe, likewiſe, depend upon the ſtructure wherein they agree; and, conſequently, it ſeems impoſſible, that two ſuch bodies ſhould have ſo many different qualities, as experience ſhews they may. Thus 'tis pretended, that the whiteneſs of froth proceeds from the multitude and hemiſpherical figure of the bubbles 'tis made up of. And if this, or any other mechanical fabric, or contexture, be the cauſe of whiteneſs; how comes it to paſs, that ſome white bodies are inodorous, and inſipid, as the calx of hart's-horn; others, both ſtrongly ſcented, and ſtrong-

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ſtrongly taſted, as the volatile ſalt of harts-horn, or of blood; ſome diſſoluble in water, as ſalt of tartar; others indiſſoluble in tha fluid, as calcin'd hart's-horn, &c. ſome fixed in the fire, as the body laſt named; others fugitive, as powdered ſal-armoniac; ſome incombuſtible, as ſalt of tartar; others very inflammable, as camphire, &c. This, I confeſs, is a conſiderable difficulty in the corpuſcular philoſophy. PHYSICS.

But, 1. I conſider, that in the pores of viſible and ſtable bodies, there may be often lodged inviſible and heterogeneous corpuſcles, to which a particular quality that belongs not to the body, as ſuch, is to be referr'd. Thus in the caſe of a perfumed glove, in the pores of the leather, odoriferous particles are harboured, which have a quite different nature from the leather itſelf, and wholly adventitious to it; yet they endue it with a fragrancy.

2. I conſider, that corpuſcles often of very different natures, if they be but fitted to convene, or to be put together after certain manners, which yet require no radical change to be made in their eſſential ſtructures, but only a certain juxta-poſition, or peculiar kind of compoſition, may, notwithſtanding their eſſential differences, exhibit the ſame quality. For inviſible changes made in the minute, and, perhaps, undiſcernable parts of a ſtable body, may ſuffice to produce ſuch alterations in its texture, as to give it new qualities, and, conſequently, different from thoſe of other bodies of the ſame kind or denomination; and, therefore, tho' there remains as much of the former ſtructure as is neceſſary to make it retain its denomination; yet it may admit of alteration, ſufficient to produce new qualities. Thus, when a bar of iron has been violently hammer'd, tho' it continues iron ſtill, and is not viſibly alter'd in its texture; yet the inſenſible parts may have been put into ſo vehement an agitation, as to make the bar too hot to be held in one's hand. And ſo if you hammer a long thin piece of ſilver, tho' the change of texture is inviſible, it will acquire a ſpringineſs that it had not before. And if you leave this hammer'd piece of ſilver a while upon glowing coals, and after let it cool, tho' your eye will, perchance, as little perceive that the fire has alter'd its texture, as it did before that the hammer had; yet you will find the elaſticity deſtroy'd. If on the ſurface of a body, a multitude of ſharp and ſtiff parts, placed thick or cloſe together, are protuberant, let the body be iron, ſilver, or wood, or of what matter you pleaſe; theſe extant and rigid parts will ſuffice to make all theſe bodies exhibit the ſame quality of roughneſs. And if all the extant parts of a phyſical ſuperficies be ſo depreſs'd, that there is a level made with the other ſuperficial parts of a body; this is ſufficient to deprive it of its former roughneſs, and give it that contrary quality we call ſmoothneſs: and if this ſmoothneſs be exquiſite, and happen to the ſurface of an opake body, of a cloſe and ſolid texture, and fit to reflect the incident rays of light undiſturb'd, this is enough to make it ſpecular, whether the body be ſteel, ſilver, braſs, marble, flint, or quick-ſilver, &c. For beſides that peculiar and eſſential modification which conſtitutes a body, and diſtinguiſhes it from all others not of the ſame ſpecies, there may be certain other attributes, that we call extra-eſſential, common to that body, with many others; and upon which

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PHYSICS. may depend thoſe more external affections of the matter, which ſuffice to give it a particular relation to other bodies; ſeveral of which relations we ſtyle qualities. Thus, provided there be a ſufficient and confuſed agitation made in the inſenſible parts of a body, whether iron, braſs, ſilver, wood, or ſtone; the vehement agitation, without deſtroying the nature of the body that admits it, will fit it for ſuch an operation, upon our organs of feeling, and upon bodies eaſy to be melted, as we call heat. And ſo in the inſtance of whiteneſs, it is accidental to it, that the corpuſcles it proceeds from, ſhould be little hemiſpheres: for tho' it happen to be ſo in water agitated into froth; yet in water frozen to ice, and beaten very ſmall, the corpuſcles may be of all manner of ſhapes, and yet the powder be white. And it being ſufficient to the production of whiteneſs, that the incident light be plentifully reflected every way undiſturbed by the reflecting body, it matters not whether that body be water or white-wine, or ſome other clear liquor, turn'd into froth; or ice, or glaſs, or chryſtal, or clarified roſin, *&c.* beaten to powder; ſince, without diſſolving the eſſential texture of theſe, formerly, diaphanous bodies, it ſuffices that there be a comminution into grains numerous and ſmall enough, by the multitude of their ſurfaces, and thoſe of the air, that gets between them, to hinder the paſſage of the rays of light, and reflect them every way plentifully and undiſturb'd. And there may be other general affections of corpuſcles, beſides the ſhape or ſtructure of them, by virtue whereof, aggregates even of ſuch as appear homogeneous, may exhibit different qualities: for inſtance, they may have ſome when they are in a briſk motion, and others when they are but in a languid one, or at reſt; as ſalt-petre, when its parts are ſufficiently agitated by the fire in a crucible, is not only fluid, but tranſparent almoſt like water; tho' when it cools again, it becomes a hard and white body; butter, that is opake, in its moſt uſual ſtate, may be tranſparent when melted; and a great quantity of beaten alabaſter, which uſually retains the form of a moveleſs heap of white powder, by being, after a due manner, expoſed to heat, obtains, without being brought to fuſion, many of the principal qualities of a fluid body. And if a glaſs be half fill'd with good ſpirit of nitre or *Aqua fortis*, it will, unleſs it be extraordinarily dephlegmed, exhibit no redneſs, or colour tending thereto; but if you warm it a little, or caſt a bit of iron or ſilver therein, to put the liquor into a commotion, then the nitrous ſpirits putting off the form of a liquor, and aſcending in that of fumes, will make all the upper part of the glaſs look of a deep yellow, or a red.

3. We have already obſerved, that a body, with regard to the production of qualities, is not to be conſider'd barely in itſelf, but as placed in, and as it is a portion of the univerſe.

Laſtly, as to that part of the grand objection we are clearing, which urges the difficulty of explaining, upon the corpuſcular principles, how, for example, the ſame body, whoſe ſtructure ſhapes it, ſo as to be fit to exhibit whiteneſs, ſhould likewiſe poſſeſs ſeveral other qualities, that ſeem to have no affinity with whiteneſs; we are aſſiſted to remove it by the paſt diſcourſe: for ſince corpuſcles, without loſing the texture eſſential to them, may,

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may, as we have ſhew'd, have their ſhape, their ſurfaces, or their ſituation chang'd; and, alſo, admit of alterations, as to motion or reſt; as to degrees, or other circumſtances of motion, as to laxity and denſity of parts; *&c.* it is certainly poſſible, that a ſingle corpuſcle, and much more that an aggregate of them, may, by ſome of theſe, or the like changes, be fitted to produce ſeveral other qualities, beſides thoſe that neceſſarily flow from it; eſpecially, ſince the qualities, commonly call'd ſenſible, and many others too, being, according to our opinion, but relative attributes, one of theſe alterations, tho' but mechanical, may endow the body it happens to, with new relations, both to the organs of ſenſe, and to ſome other bodies, and, conſequently, with additional qualities.

If from good *Venice* turpentine, you gently evaporate about a third part of its weight, you may obtain a fine tranſparent, and, almoſt, reddiſh colophony. Beat this very ſmall, it will loſe its colour and tranſparency, and afford an opake, and very white powder; expoſe it to a moderate heat, and it will quickly, without violence, both regain its colour and tranſparency, and become fluid; and, if whilſt it is thus melted, you put the end of a reed a little beneath the ſurface, and dexterouſly blow into it, you may obtain bubbles adorn'd with very various and vivid colours. If, when it has loſt its fluidity, and remains tolerably warm, you take it into your hands, you will find it has, in that ſtate, a viſcoſity, by virtue of which, you may, like paſte, draw it out into threads; but as ſoon as it grows quite cold, it becomes exceeding brittle; and if whilſt it is yet warm, you give it the ſhape of a triangular priſm, and make it of a convenient bulk, it will exhibit variety of colours, almoſt like a triangular glaſs. Whilſt this colophony, is cold, and its parts are not put into a due motion, ſtraws, and other light bodies, may be held unmov'd cloſe to it; but if by rubbing it a little, you agitate the parts, tho', perhaps, without ſenſibly warming the colophony, it manifeſts an electrical quality, and readily draws to it ſtraws, and other light bodies that it would not move before. Though urine be eſteem'd a homogeneous body, and, tho' it loſes its texture by putrefaction, before it is diſtill'd; yet when it has been twice or thrice rectified, the ſpirits of it, ſwimming in a phlegmatic vehicle, leave a pungent ſaltneſs upon the tongue, and a very ſtrong and offenſive ſmell; and when freed from the water, they are white to the eye, and exceeding ſharp to very tender and excoriated parts, and burn like a cauſtic; ſo that I have ſeen them preſently make bliſters upon the tongue; and the ſame ſaline particles inviſibly flying up to the eyes, prick them, and make them water; and invading the noſe, often cauſe that great commotion in the head and other parts of the body, we call ſneezing. The ſame corpuſcles, if ſmelt to by a woman in hyſterical fits, very often ſuddenly relieve her; and ſo may be reckon'd among the ſpecific remedies of that odd diſeaſe. The ſame corpuſcles taken into the human body, have the qualities that, in other medicines, we call diaphoretic and diuretic: the ſame particles put upon filings of braſs, produce a fine blue; but upon the blue or purple juices of many plants, they preſently produce a green: being put to work upon copper, whether crude or calcined, they readily

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PHYSICS. diſſolve it, as corroſive menſtrua do other metals; and yet the ſame corpuſcles being blended, in a due proportion, with the acid ſalts of ſuch menſtrua, have the virtue to deſtroy their corroſiveneſs; and if put into ſolutions made with ſuch menſtrua, they have a power, excepting in very few caſes, to precipitate the bodies therein diſſolv'd. Now, this ſpirituous ſalt being a factitious body made out of a putrefied one, and ſo ſimple as to be a chymical ſalt, or one of the three chymical principles of compound bodies; it muſt the rather be allow'd to work by virtue of its mechanical properties. And to confirm this the more, I ſhall add, that if you compound it with the ſaline particles of common ſalt, which is, alſo, a factitious thing, and confeſſed by chymiſts to be a ſimple principle; theſe two being mixed in a due proportion, and ſuffer'd leiſurely to combine, they will aſſociate themſelves into corpuſcles, wherein the urinous ſalt loſes moſt of the qualities I have aſcribed to it; and, with the acid ſpirit, compoſes, as I have often try'd, a body little different from ſal-armoniac: which great change, can be aſcribed to nothing ſo probably, as to that of the ſhape and motion of the urinous ſalt, which changes the one, and loſes a great part of the other, by combining with the acid ſpirits. And to confirm that both theſe happen, I have, ſeveral times, ſlowly exhaled the ſuperfluous liquor from a proper mixture, made of the ſpirit of urine, and that of ſalt; and found that there remained in the bottom, a ſalt not only far more ſluggiſh than the fugitive one of urine, but whoſe viſible ſhape was quite different from that of the volatile cryſtals of urine; this compounded ſalt being generally figured either like combs or feathers.

And now, if to all this we add, that the extra-eſſential changes, which may be made in the texture, ſhape, motion, *&c.* of bodies, agreeing in their eſſential modifications, may not only qualify them to work immediately, after a different manner upon different organs of ſenſe, and upon other bodies, whoſe pores, *&c.* are differently conſtituted; but may diſpoſe them to receive other impreſſions than before, or to receive the uſual ones after another manner, from the more univerſal agents of nature; it muſt appear that the propoſed ſcruple, is not ſo perplexing to our philoſophy, as might be at firſt imagined.

The three difficulties ſpoke to, were thought fit to be here conſidered, becauſe there are many things in my other writings, which refer to the preſent; becauſe the ſcruples themſelves, are of great moment, and have not been diſcuſs'd by others; and becauſe the difficulties relating to the corpuſcular hypotheſis, in general, the ſolution of them may both ſerve to confirm ſeveral of the particulars, mentioned in giving the origin of forms and qualities, and conduce to clear and explain ſeveral other phenomena of nature.

SECT. IX.

Cofmical, or ſyſtematical qualities introduced.

THE qualities of particular bodies, for the moſt part, conſiſt in relations, upon account whereof, one body is fitted to act upon others, or diſpoſed to be acted upon by them, and receive impreſſions from them; as quick-

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ſilver has a quality or power to diſſolve gold and ſilver; and a capacity, or diſpoſition, to be diſſolved by *Aqua fortis*, and *Aqua regis*. And tho' in eſtimating the qualities of natural bodies, we uſually conſider only the power that any particular one has of acting upon, or its capacity of ſuffering from others, wherewith it is obſerved to have a manifeſt commerce, in making or receiving impreſſions; yet there may be ſome attributes belonging to a particular body, and ſeveral alterations to which it may be liable, not barely upon account of thoſe qualities that are preſumed to be evidently inherent in it, nor of the reſpects it bears to thoſe other particular bodies whereto it ſeems manifeſtly related; but upon account of a ſyſtem conſtituted, as our world is, of ſuch a fabric, that there may be many unheeded agents, which, by unperceived means, have great operations upon the body we conſider; and work ſuch changes in it, and enable it to work ſuch changes on other bodies, as are rather to be aſcribed to ſome unheeded agents, than to thoſe other bodies, with which the body propoſed is obſerved to be concern'd. So that if many bodies, which I could name, were placed together in ſome imaginary ſpace beyond the bounds of our ſyſtem, tho' they would retain many of the qualities they are now endow'd with; yet they could not poſſeſs them all; but by being reſtored to their former places in this world, they would regain a ſet of faculties and diſpoſitions, depending upon ſome unheeded relations and impreſſions from the determinate fabric of the grand ſyſtem or world, whereof they are parts; and theſe are what I call coſmical, or ſyſtematical qualities. PHYSICS.

I have, already, ſlightly touch'd upon this ſubject, in ſhewing the origin of forms, but otherwiſe there than I at preſent intend. I there, principally, obſerve, that one body being ſurrounded with others, is manifeſtly wrought upon by many of them: but here I ſhall chiefly conſider the impreſſions a body may receive, or the power it may acquire from thoſe vulgarly unknown, or unregarded agents, by which it is affected, not only upon the account of its own peculiar texture or diſpoſition, but by virtue of the general fabric of the world.

The obſervations whereon I found my notions of coſmical qualities, are principally theſe.

1. There are many bodies, that, in ſeveral caſes, act not, unleſs acted upon; and ſome of them act either ſolely, or chiefly, as they are acted on by general and unregarded agents.

2. There are certain ſubtile bodies in the world, that are ready to inſinuate themſelves into the pores of any other, diſpoſed to admit their action, or that in ſome way affect it; eſpecially if they have the concurrence of other unobſerved cauſes, and the eſtabliſhed laws of the univerſe.

3. A body, by a mechanical change of texture, may acquire or loſe a fitneſs to be wrought upon by unheeded agents, and, alſo, to diverſify their operations on it, by a variation of its texture.

Theſe three propoſitions I ſhall confirm diſtinctly, by experiments and phenomena: but as ſeveral of the proofs may each ſerve to confirm more than one of the propoſitions, I leave them to be referr'd thereto occaſionally.

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PHYSICS. To begin with the first proposition.

PROP. I.

There are many bodies, that, in several cases, act not, unless acted upon; and some of them act either solely, or chiefly, as they are acted on by general and unheeded agents.

The former part of the proposition will, I presume, be easily granted, being evident from such gross instances as these, that a wedge will not cleave a block, unless forcibly impell'd against it; nor a knife attract a needle, unless excited by a magnet. But the second will not, probably, be so readily assented to.

We see however, 1. that concave specula, and convex burning-glasses, kindle not other bodies, unless enabled to do it by the reflected or refracted beams of the sun.

2. An iron bar left in a window, or some other fit place, in a perpendicular posture, tho' it was not, when first erected, endowed with magnetism, more than other iron bars of the like shape and bigness; yet after it hath long stood in that position, it will, by the operations of invisible agents, acquire a farther degree of magnetism than belonged to it as a bar of iron, and be enabled to produce some magnetical phenomena, that it could not before.

And, 3. a very flat and exquisitely polish'd piece of marble, tho' of itself it hath no power to raise any other dry body it is laid upon; yet, if it come to be carefully applied to another piece of marble, as flat and smooth as itself, and of a bulk not too unwieldy, the upper stone, by virtue of the fabric of the world, which gives the ambient air fluidity and weight, is enabled, without any other cement or fastening instrument, than immediate contact, to raise with itself, when lifted, the lower, tho', perhaps, an hundred times heavier than it.

We come now to our second proposition.

PROP. II.

There are certain subtile bodies in the world, ready either to insinuate themselves into the pores of any body disposed to admit their action; or, by some other way to affect it; especially if they have the concurrence of other unobserved causes, and the established laws of the universe.

The antient philosophers thought there was a more subtile body than common air, called æther; and the *Cartesians* tell us, there is such a substance diffused throughout the universe; which they call, according to the different sizes of its parts, sometimes *primum elementum*, and sometimes *materia cœlestis*, which they suppose pervades all other bodies, adequately filling those of their pores that are correspondent, in bigness and figure, to the different portions of this insinuating matter. That there may be such a substance in the universe, the assertors of it, will, probably, bring for proofs, several of the following phenomena. But whether there be, or be not, in the world, any matter that exactly answers to the descriptions they make of their first and second elements, I shall not here determine; tho' many experiments seem to argue, that there is in the world, an etherial substance very subtile and diffused. But the invisible agents I shall here chiefly take notice of, will be the air, and the magnetical effluvia of the terrestrial globe. If

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If you make a bar of ſteel, and another like it of ſilver, red-hot, and put them to cool directly north and ſouth; tho' they be both acted upon by the ſame agent, the fire; and tho' the ſteel, as to ſenſe, ſeems ſuch as it was before; yet the texture of theſe two metals being different, the ſilver acquires no new quality by what hath been done to it; but the ignition of the ſteel having open'd its pores, and made its parts more pliable; as may be argued from the ſwelling of iron heated red-hot, and its ſoftneſs under the hammer; it is eaſily, whilſt it lies north and ſouth, pervaded by the magnetical effluvia of the earth, which glide perpetually through the air from one pole to another; and by the paſſage of theſe ſteams, it gains a magnetical property, which ſome call polarity, whereby, being freely ſuſpended, and exactly poiſed, it will, as it were, ſpontaneouſly direct itſelf north and ſouth, and exerciſe ſome operations peculiar to magnetical bodies. Nay, the earth has a power to impart, in ſome caſes, a directive faculty to the load-ſtone itſelf. For having, by ignition, deprived an oblong magnet of its former attractive power, by taking it red-hot out of the fire, and ſuffering it to cool north and ſouth, I could, at pleaſure, by placing either end northward or ſouthward, whilſt the ſtone was cooling, make what end I pleas'd, point to the north-pole; and when it had done ſo, I could, by a new ignition, and cooling of it in a contrary poſition, make the ſame end of the ſtone become its ſouth-pole. PHYSICS.

If you take a capacious glaſs vial, with a ſlender neck ending in a ſharp angle, with only a pin-hole left open at the apex, and by ſuction, or otherwiſe, free it from as much of the included air as you can; and then, having ſtopp'd this hole with your finger, you immerſe it deep under water, and withdraw your finger, the water will, contrary to its own gravity, ſpring up with violence to a great heighth into the cavity of the vial: which motion of a heavy liquor upwards, cannot be aſcribed to the motion of the finger, for that did but unſtop the orifice, and not impel up the water; nor need it be attributed to nature's abhorrence of a vacuum, which it is altogether unneceſſary to have recourſe to in this caſe; the preſſure of the ambient air, proceeding from its weight upon the ſurface of the water, being ſufficient to force up that liquor into the vial, in which the remaining air, by being rarified, upon the abſence of a large part, hath its ſpring too much weaken'd to reſiſt the preſſure of the outward air, as before: but if this experiment were try'd *in vacuo*, the water would not riſe, there being no outward agent to impel it.

I had once occaſion to pluck ſome beans and peaſe, out of the ground where they grew, and after having taken notice of their ſwelling upon imbibing the moiſture of the ſoil, and of their way through the earth, not only upwards with their ſtems, but downwards with their roots; I thought fit to try with what force the cauſes of their intumeſcence endeavour'd to dilate them. Upon this, I fill'd ſeveral ſtrong vials and bottles, with horſe-beans, the intervals between the beans being fill'd with water, and the veſſels exactly ſtopp'd with corks, ſtrongly ty'd down, that nothing might get out: for I ſuppos'd, that the water ſoaking into the pores of the beans,

would

PHYSICS. would alter the figure of the pores, and produce in them an endeavour to ſwell, which being check'd by the ſides and ſtopples of the veſſels, would diſcover, whether that endeavour were ſo forcible as I ſuſpected. The ſucceſs was, that moſt of theſe veſſels, whether of glaſs or earth, were burſt aſunder; the ſtrings wherewith the ſtopples were ty'd, breaking in the others.

To make a nearer eſtimate of the expanſive force of the ſwelling beans, we put a convenient quantity of them into a ſtrong hollow cylinder of braſs, whoſe cavity was ſix inches in length, and two in diameter; then having pour'd in water enough to reach the top of the beans, we put into the upper part of the cylinder, which was purpoſely left unfill'd, a wooden plug made fit for the orifice, but a little narrower, that it might move freely up and down, tho' the water ſhould make it ſwell. At the top of this plug, was left a thick piece of wood, broad and round, whereon we placed a common half hundred weight, which yet could not depreſs the plug too low, being hinder'd by the breadth of the round piece of wood. Laſtly, having kept the cylinder in a quiet place, for a fit time, which is ſometimes two or three days, more or leſs, according to the temperature of the air, and quantity of the included matter, we obſerv'd, that the ſwelling beans had very manifeſtly rais'd the plug, and the incumbent weight, beyond the former ſtation.

I was willing to try whether this force would not, in cylinders of different ſizes, be increas'd in a duplicate proportion to that of their diameters; but could not make ſuch an experiment as I deſir'd. I diſcover'd, however, that the preſſure, upwards, was very much greater in wide cylindrical veſſels, than in narrow ones; for, having put a convenient quantity of dry'd beans, into a metalline cylinder, not ſix inches deep, nor four broad; when the included beans began to ſwell, they manifeſtly rais'd ſuch a plug as we juſt deſcrib'd, clogg'd with above an hundred pound weight.

Whether this may paſs for a new phyſical moving power, I ſhall not determine; and leave it to be conſider'd, whether, by mechanical contrivances, ſo great a force as might this way be produced; and which ſlowly, and ſilently proceeds, till it hath attain'd its utmoſt energy, and is capable of being convey'd into bodies, without working any effect before the due time, may not, in ſome caſes, be applicable to uſeful purpoſes.

We might here obſerve, that the air, with the æther harbour'd in its pores, may, by its conſtant preſence, or by its being always at hand, and ready to inſinuate itſelf, wherever it can get admittance, concur to the production of ſeveral phenomena, where its co-operation has not been ſuſpected by philoſophers. For the preſence of the air, to preſs upon the ſuperficies of liquors, is ſo requiſite in ſuction, that they will not, thereby, be made to aſcend without it; and ſome bodies will not, readily, be brought to putrefaction, if the air be, a-while, carefully excluded. Nay, the light which appears in ſome rotten woods, and in putrefied fiſh, ſo much depends upon the preſence of the air, as to diſappear, if that be quite withdrawn from them; but when reſtored to the contact of the air, they will, again, ſhine as before.

But,

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But, beſides what the air, and the more ſubtle matter mix'd with it, does as a ſubſtance, it may perform ſeveral things upon other accounts; as its finer parts may be inſenſibly moved in ſtrait lines, or, as it is the ſubject of ſwarms of corpuſcles, put into peculiar, tho' inviſible motions. For inſtance; if I take a ſheet of paper, and rub it over with oil; that which the liquor apparently does, is only to pierce or ſoak into the pores of the paper; which before did, by their crookedneſs, or upon ſome other mechanical account, render the paper opake. But this inſinuation of the unctuous body into the pores, having alter'd them as to figure, ſize, or both; and by that alteration given the paper a texture diſpoſed to allow due paſſage to the corpuſcles of light; the motions, or inviſible corpuſcles of the air, depending upon the conſtitution of the world, preſently act upon the paper, and produce beyond it, both a ſenſation of light, and the repreſentations of a multitude of objects, whence the light reflects, and which could not be ſeen thro' it before. PHYSICS.

If a box be ſo contriv'd, that there may be, towards one end of it, a fine ſheet of paper, ſtretch'd like the leather of a drum-head, at a convenient diſtance from the remoter end; where there is to be left a hole fitted for the purpoſe; you may, at a little hole left at the upper end of the box, ſee upon the paper, very lively and pleaſing repreſentations, not only of the motions, but ſhapes and colours of external objects. And, ſince upon turning this inſtrument, or *Camera obſcura*, any way, new objects every where ariſe, and ſometimes new landſcapes upon the paper; there muſt be, all day long, in all parts of the air where this phenomenon is exhibited, either certain *effluvia*, emitted on all ſides of the objects, or certain motions of inſenſible corpuſcles, which, rebounding firſt from the external object, and then from the paper, produce in the eye, the images of theſe objects: ſo that the air is every where full of viſible ſpecies, which cannot be intelligibly explain'd, without the local motions of ſome minute corpuſcles, that, whilſt the air is enlighten'd, are always paſſing thro' it.

I include the eſtabliſh'd laws of the univerſe in our ſecond propoſition, as a part of the preſent conſtitution of our ſyſtem; becauſe ſome of thoſe laws greatly contribute to the operation of the unheeded cauſes we are treating of. Thus, for inſtance, if you take a bar of iron, and holding it perpendicularly, apply the loweſt part of it to the northern point of a well-poiſed magnetical needle, the bar will preſently drive it away; but that magnetiſm, by which the bar does this, as 'tis preſently acquired by the poſture it had, ſo 'tis as ſuddenly changed, if you invert that poſture; for if you hold the bar perpendicularly under the needle, ſo that the ſame part, which before was placed directly over the north point of the needle, comes directly under the ſame point; the bar will not, as before, repel, but attract it: but if this bar has been, for a long time, kept in an erect poſture; as, if it be taken from ſome old window, or if having been heated and cooled, it has very long lain north and ſouth; it will appear endow'd with a ſtronger and more durable verticity; which ſeems to proceed from hence, that, by lying north and ſouth, it lay in the way, which, according to the eſta-

PHYSICS. eſtabliſh'd laws of nature, the magnetical *effluvia* of the earth muſt paſs along in ſtreams from pole to pole; whereby they have the opportunity gradually to work upon the pores of the iron in their courſe, and fit them to give paſſage to the *effluvia* of magnetical bodies; in which fitneſs the magnetiſm of iron ſeems principally to conſiſt: but if this metal had all the while lain eaſt and weſt, inſtead of north and ſouth, it would have acquired no magnetical virtue. And the reaſon why an erect poſture gives a rod of iron a power to drive away the north point of the needle, is, probably, this; that the lower end, being nearer the earth, more plentifully participates of the magnetic *effluvia*, which fly in a cloſer order there, than farther off; and, by powerfully affecting that part of the iron, turn it, for a time, into the iron's north pole; which, according to magnetical laws, ought to drive away the north pole of the needle, and attract the ſouth: whereas, if the bar being inverted, that end which was uppermoſt becoming the lower, muſt, for the ſame reaſon, have a contrary effect; unleſs, by having ſtood long, its verticity be too well ſettled, to be ſuddenly deſtroy'd, or alter'd by the *effluvia* of ſo languid a magnet as the earth. But whether this ſolution be juſt, or no, it appears, by the neceſſity both of a determinate poſition of the iron, and its long continuance in that poſition, to make the metal acquire a durable verticity, that thoſe unheeded magnetical ſteams, which communicate ſuch a magnetiſm to the iron, move and act according to laws eſtabliſh'd in nature; which is all my preſent deſign requires.

To come to our third and laſt propoſition.

PROP. III.

A body, by a mechanical change of texture, may acquire or loſe a fitneſs to be wrought upon by unheeded agents, and alſo to diverſify their operations on it, by a variation of its texture.

'Tis a cuſtom at ſea, when the ſhip ſails with too ſlack a wind, to throw water againſt the ſails. At the firſt, this may ſeem a very improper means to promote the way of the ſhip, ſince there is the weight of ſo much water added to that of the veſſel; yet I have ſeen the ſeamen uſe it as one of their beſt expedients, when we were cloſely chaſed by pirates: nor is it irrational; for when the ſails are dry, a large part of the wind that blows upon them, eaſily paſſes thro' thoſe meaſhes, or large pores that are left between the threads, of which a ſail conſiſts; but being wetted, the imbibed water makes the threads ſwell every way, and, conſequently, much contracts the pores or intervals between them; whence the wind cannot paſs them ſo freely as before; but, finding a greater reſiſtance in the ſail, beats more forcibly upon it.

But farther, tho' good common tartar, uſually of itſelf, keeps dry in the air, and will not eaſily diſſolve in cold water; yet, if it be calcined, tho' but very moderately, the ſalt in the remaining coal, the texture being now altered, will readily run in the moiſt air. Having heated and cooled a loadſtone, tho' it had loſt ſo little by the fire, that the eye diſcover'd no change, either

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either in its ſhape or bulk; yet the operation of the fire, by changing the inviſible texture, ſo alter'd the diſpoſition of it, with regard to the magnetical *effluvia* of the earth, that I could preſently change and alter the poles of the ſtone, making the ſame end point ſometimes to the north, and ſometimes to the ſouth. The like change of verticity I have alſo made mere iron capable of, without the help of fire, or any other magnet, than the earth: and I find by trial, that a certain heavy ſtone, uſually thought to be not of a metalline nature, may, by a ſlight and quick preparation, that alters not its bulk or ſhape, be enabled to attract and repel the poles of a magnetic needle. PHYSICS.

To the inſtances already given in ſolid bodies, it will not be amiſs to add two or three in fluids. If honey and water be, each of them apart, put into a convenient veſſel, they will both retain their nature, and tho' you ſhou'd mix them together in an undue proportion, ſo that by reaſon of too much honey, the conſiſtence be too thick; or if by being diluted with too large a proportion of water, the ſolution be too thin, they may ſtill continue honey and water; but if they be duly proportion'd, as if you put to one part of honey, 4 or 5 of water, then their new texture ſo diſpoſes them to be acted on by the ſubtile matter, or whatever other common agent nature employs to produce fermentations, that the ingredients no longer continue what they were, but begin to work like new muſt or wort: and I have try'd, that ſo ſmall and ſhort a local motion, as that of a coach, for a while, has ſo excited ſuch a liquor, as to make it violently force its way out of the veſſel, or throw out the ſtopple. And an eminent wine-merchant, who lived many years in the *Canaries*, aſſured me, he had there ſeveral times obſerv'd, that if a pipe of the beſt ſort of canary were, when it was about a month old, rudely roll'd, tho' but the length of a hall or gallery, ſo tranſient and ſlight a diſcompoſure of the texture, would quickly make ſo great a change in it, that often a large quantity of wine would be violently thrown out at the bung; or, if the pipe were too cloſe ſtopped, it would have its head, or bottom, beat out.

We have numerous inſtances of the cracking of common glaſs, when it is, too ſoon after being removed from the fire, expoſed to the cold air, and the ſubtile bodies that are in it; which would not have crack'd it, if it had cooled more ſlowly, ſo that its parts might have had leiſure to ſettle into a texture, convenient for the paſſage of thoſe ſubtile bodies; which, in that caſe, would have freely pervaded it. But I have, ſometimes, given a more quick and manifeſt inſtance of the importance of the preſent texture of a body, with regard to the univerſal and inviſible cauſes, that may work upon it: for having heated a plate of copper red-hot, and then ſuffered it to cool a little, on ſome leſs hot part of the fire, ſo that it might not appear at all ignited when removed, to a ſheet of paper; yet, upon its being expoſed to the atmoſphere, the ſuperficial part would not only crack as a glaſs haſtily cooled, but preſently fly off in numerous flakes, and not without noiſe; ſo that, in a ſhort time, I have had the ſurrounding part of the paper, on which the plate reſted, almoſt quite covered with little ſcales,

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PHYSICS. as it were, of that metal. And the *Bolonian* ſtone, by calcination, acquires this property, that if expoſed to the ſun-beams, or other ſtrong light, it will, in a few minutes, appear luminous; and, for ſome time, continue ſo in the dark.

SECT. X.

Coſmical ſuſpicions as to ſome unobſerv'd laws and orders of nature.

I Have had ſome faint ſuſpicion, that beſides thoſe more numerous and uniform ſorts of minute corpuſcles, which are by ſome of the modern philoſophers thought to compoſe the æther, there may, poſſibly, be ſome other kind of corpuſcles fitted to produce conſiderable effects, when they find bodies proper to be wrought on by them. But, tho' 'tis poſſible that theſe effects may be plauſibly explain'd by the æther, as 'tis already underſtood; yet, I ſuſpect they are not ſolely due to the cauſes aſſign'd them, but, in ſome meaſure, to the corpuſcles above-mentioned.

In the æther of the ancients, there was nothing taken notice of but a diffuſed and very ſubtile ſubſtance; yet we are, at preſent, content to allow, that there is always in the air a ſwarm of ſteams, moving in a determinate courſe betwixt the north and ſouth poles; which we ſhould not probably have dream'd of, if our inquiſitive *Gilbert* had not happily found out the magnetiſm of the terreſtrial globe. And few, perhaps, would have imagin'd, that when a hunted deer has ſwiftly paſs'd over a little graſs, he ſhould leave upon it ſuch determinate, tho' inviſible *effluvia*, as will, for many hours, ſo impregnate the air as to betray the individual flying and unſeen deer, if there were no blood-hounds, whoſe peculiar organs of ſcent thoſe ſteams are fit to affect. And 'tis ſtrange, there ſhould be ſuch *effluvia* for a long time reſiding in the air, that tho' our ſenſes diſcern them not, and tho' they have no operation upon other men; yet, if they meet with perſons of a peculiar temper, who having formerly had the plague, thereby obtain a peculiar diſpoſition that fits them to be affected by peſtilential ſteams, they may ſo operate upon them, that theſe perſons ſhall be able to diſcern thoſe ſteams to be peſtilential. Above three months before the great plague began in *London*, in the year 1665, there came a woman to a phyſician of my acquaintance, to deſire his advice for her huſband, whoſe chief diſtemper, ſhe ſaid, was a ſwelling in his groin; and added, that he was confident the plague would rage vehemently in *London* next ſummer. His reaſon was, becauſe in the laſt great plague he fell ſick of that diſeaſe, and then had a peſtilential tumour; and becauſe two other leſs plagues were each of them preceded by a riſing in his body; and now having a great tumour in the fore-mention'd place, he doubted not but it would be follow'd by a raging peſtilence. This I had from the Doctor himſelf, a perſon of great veracity.

Fabricius Hildanus records of himſelf, that having had a peſtilential tumour during a plague that happen'd in his youth, if, for many years after he chanced to go to, or even paſs by a houſe infected with the plague, he

was

was admoniſh'd of the particular diſeaſe that reign'd there, by a ſenſible pain in the part where his tumour had been. PHYSICS.

That curious obſerver of the phenomena of diſeaſes, at the famous ſiege of *Breda*, where he practis'd much among patients afflicted with malignant and peſtilential diſeaſes, was, at length, himſelf infected; upon which he tells us, "it well deſerves to be remark'd, that the admonition of nature "may prove very ſerviceable in preventing the plague. I obſerv'd in "myſelf," ſays he, "when I viſited ſuch as were infected, that I preſently "felt a pain in my groin, or arm-pits; ſometimes my head was ſeiz'd, "and then I ſweat in the night, and afterwards had three or four ſtools: "others alſo aſſured me, that the like happen'd to them." And here the judgment of theſe two writers, the profeſſion they were of, and their relating things that often happen'd to themſelves, may well gain credit to what they ſay. Theſe inſtances, added to what has been already ſaid, may make it proper to conſider, whether there are not other, and unobſerv'd ſorts of *effluvia* in the air, about which, to declare a poſitive opinion, is not what I pretend to.

And, as I take in the ſtructure and eſtabliſh'd laws of the univerſe, to account for the coſmical attributes of things; I muſt here confeſs, that I fear we have not yet attentively conſider'd either of the number, or the kinds of thoſe laws.

I am inclined to think there may be a greater number of the more general laws, than have yet been diſtinctly enumerated. When we ſpeak of the eſtabliſh'd laws of nature, in the more popular ſenſe of that phraſe, I imagine they may be juſtly and commodiouſly diſtinguiſh'd; ſome of them being general rules, that are very extenſive, and of greater affinity to laws, properly ſo call'd; and others ſeeming to be not ſo much general rules, or laws, as the cuſtoms of nature, in a particular part of the world; of which there may be a greater number, and theſe may have a greater influence on many phenomena of nature, than we uſually imagine.

But as the ſtructure of the world is a great help to our preſent inquiry, I ſhall venture to ſay, that tho' I admire the induſtry of aſtronomers and geographers, yet they have preſented us rather a mathematical, than a phyſical hypotheſis of the univerſe; having ſhewn us the magnitudes, ſituations, and motions of the fix'd ſtars, and the planets, without being ſolicitous to declare what more ſimple and compound bodies the globe we inhabit may conſiſt of. And as, of late, the diſcovery of the four planets about *Jupiter*, with the phenomena of comets, have made a reformation in the theory of the celeſtial bodies; ſo future diſcoveries may, perhaps, reduce us to make changes in the grand ſyſtem of the univerſe itſelf; and in that which we conſider as the moſt important of the mundane bodies to us, the terraqueous globe.

What communication this may have with the other globes we call ſtars, and with the interſtellar parts of the heavens, we know but very little. I confeſs, I have ſometimes ſuſpected, that there may be in the terreſtrial globe

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PHYSICS. itself, and the ambient atmosphere, several laws, or customs of nature, that belong to this orb, and may be denominated from it, which yet, seem to have been either unknown, or overseen, both by scholastic and mathematical writers.

And, first, I have often suspected, that there is in the mass of the earth, some great, tho' slow internal change; from considering, that almost in all countries, where observations have been made, there has a plain and considerable alteration appear'd in the variation, or rather, declination of the magnetic needle; which is the distance by which the needle declines east, or west, from the true north pole. Near *London*, the compass declined in the year 1580, above 11°; in the year 1612, above 6; in the year 1633, about 4; and it has, of late, been found to have little or no variation. And, at a place within half a league of *London*, trying with a long and curious needle, purposely made and pois'd, I could scarce discern any declination at all: and if the needle declined sensibly any way from the pole, it seem'd to do so a little more towards the other side, than that towards which it declined before. And having in the year 1669, by the help of an exact meridian line, made an observation at *London* itself, with two instruments, one whereof was extraordinary, and different from the other, I could not discern the declination of the needle to exceed half a degree. But since observations of this kind may prove more considerable, than we are aware of; and since they ought to be made at distant places; I shall add, that the *Cape* of *Good Hope* being one of the most eminent parts of the terrestrial globe, an ancient and most experienced navigator of my acquaintance, assured me, that when he was a young seaman, he observ'd the variation there to be about 2° westward; and afterwards, during many years that he sailed betwixt *East-India* and *Europe*, he found it to increase gradually. And, as he learned from ancient writings, and the traditions of old seamen, that, before his time, they had found no variation at all, he, about 15 years ago, which was the last time he took it, found it, by accurate instruments, to be 6°, and about 48′, so that during the time he used the seas about the *Cape* of *Good Hope*, the variation, still westward, had decreas'd near 5°. Hence, I cannot but think it probable, that there may be agents we know not of, that have a power to give the internal parts of the terrestrial globe a motion, tho' we cannot yet certainly tell, according to what laws 'tis regulated, or so much, as whether it be constantly regulated by certain laws, or no. And what other alterations agents that can produce a change in the terrestrial globe itself, may make in particular parts of it, who can inform us?

We may, next, consider the great uncertainty, and irregularity *hitherto* observ'd in the weight of the atmosphere, by our new statical barometers; and much more sensibly by mercurial ones, yet without having discover'd the causes of such considerable alterations in the air; except that, in general, they proceed from subterraneal steams, whose influences upon other things may be more considerable than we have yet had opportunity to observe.

'Tis

'Tis very remarkable, what M. *de Rochfort*, who liv'd in ſome of the *American* iſlands, relates about the hurricanes in thoſe parts, *viz.* that before the *Europeans* came thither, the inhabitants obſerv'd they had thoſe fatal tempeſts once in ſeven years; and no oftner; afterwards they were troubled with them but once in ſix years; and, at length, they grew ſo frequent, that, in our author's time, they return'd every year; and, as they once obſerv'd, twice in one year; and, afterwards, thrice in another. And, an inquiſitive Gentleman, who had liv'd in *New-England*, aſſur'd me, there was a great change made in the temperature of the climate of that country, it being grown much milder than formerly; as had been obſerv'd for many years after the *Engliſh* planted a colony there: the change was manifeſtly perceiv'd by the natives; and appear'd, alſo, by the ſlow operation of the cold upon the waters, which were formerly frozen at particular times. And, having the honour to ſtand by his majeſty, when he receiv'd an addreſs from *New-England*, preſented by the governour of a colony there, the king aſking him about the temperature of the air of that country, he reply'd, in the preſence of ſeveral who came from *America* with him, that "the climate had much alter'd, and loſt of its former coldneſs, for ſeveral "years, ſince the *Engliſh* ſettled there." Whether this decreaſe of the ſharpneſs of the air will proceed, or how long it will continue, time muſt diſcover. But, ſuppoſing the matter of fact to be true, and that the change depends not on any manifeſt cauſe; what has happen'd already, ſeems, to me, very conſiderable; ſince, in a book intitled, *New England's Proſpect*, written by Mr. *Wood*, one of the ancient planters of *New-England*, there is this notable paſſage. "In former times, the rain came ſeldom, "but very violently, continuing its drops, which were great and many, "ſometimes 24 hours together, ſometimes 48; which water'd the ground "for a long time after; but, of late, the ſeaſons are much alter'd; the "rain coming oftner, but much more moderately, with leſs thunder and "lightning, and ſudden guſts of wind." And, again, ſpeaking of the heathen natives, he ſays, "they acknowledge the power of the *Engliſhman's* "God, as they call him, becauſe they could never yet have the power, by "their conjurations, to damnify the *Engliſh*, either in body, or goods; and, "beſides, they ſay, he is a good God, that ſends them ſo many good things; "ſo much good corn, ſo many good cattel, temperate rains, fair ſeaſons; "which they, likewiſe, are the better for, ſince the arrival of the *Engliſh*; "the times and ſeaſons being much alter'd in ſeven or eight years; free "from lightning and thunder, long droughts, ſudden and tempeſtuous daſhes "of rain, and lamentable cold winds." Hence it appears that this decreaſe of the coldneſs, and ſeverity of that climate, were taken notice of many years ago; for 'tis now 35 years ſince this book was publiſh'd. PHYSICS.

Magnetus tells us, in his treatiſe of manna, that, in the country he calls *Cenotria*, there was no manna to be found a little above three hundred years ago. And that in *Calabria* itſelf, which furniſhes a great part of *Europe* with that drug, 'tis but two ages ſince, or thereabouts, that manna has fallen. 'Tis ſeriouſly affirm'd to me, by ſober perſons, from their

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PHYSICS. their own experience, that the ſpots made in linen, by the juices of fruit, and particularly of red currans in ſtraining bags, will beſt waſh out, and ſcarce otherwiſe, at that time of the year, when thoſe fruits are ripe the enſuing year.

The ingenious *French* writer of the hiſtory *des Iſles Antilles*, where he lived ſeveral years, ſpeaking of the fruit they there call *Acajou*, tells us, that the juice of ſome of the internal parts of it, tho' reputed an excellent remedy in fainting fits, is of ſuch a nature, that if it chance to fall upon a piece of linen, it turns to a red ſpot, that laſts till the tree comes to be again in flower; which phenomena, (if the length of time, and the heat and temperature of the air, uſual in the ſeaſons of producing bloſſoms, and ripening of fruits, be found to have little ſhare in their cauſe) may prove of ſome uſe in our preſent inquiry.

Whatever be the true cauſe of the ebbing and flowing of the ſea, yet, at ſpring-tides, the motions of ſuch vaſt maſſes of matter, as the great ocean, and moſt of the ſeas, are ſo conſtantly co-incident with the new and full-moon; and the more ſtupendous ſpring-tides have been, in moſt places, ſo long obſerv'd to happen regularly about the equinox, that it is worth an enquiry whether theſe conſpicuous phenomena may not, ſomewhat confirm the conjectures we are diſcourſing of.

And, recollecting how many queſtions I have put to navigators, about the luminouſneſs of the ſea, which, in ſome places, ſhines in the night, as far as the eye can reach; at other times and places, only when the waves daſh againſt the veſſel, or the oars ſtrike and cleave the water; that ſome ſeas ſhine often, and others have not been obſerv'd to ſhine; that, in ſome places, the ſea has been obſerv'd to ſhine, when particular winds have blown, whilſt, in other ſeas, the obſervation holds not; and that in the ſame tract of ſea, within a narrow compaſs, one part of the water will be luminous, whilſt the other is dark: I ſay, recollecting many of theſe odd phenomena, which have been told me by very credible eye-witneſſes, I am tempted to ſuſpect, that ſome coſmical law, or cuſtom of the terreſtrial globe; or, at leaſt, of the planetary vortex, may have a conſiderable ſhare in the production of ſuch effects.

Nor am I ſure, that ſome ſubterraneal change, or ſome yet unobſerv'd commerce between the earth, and other mundane globes, has not an intereſt in the origin, continuance, and ceſſation of thoſe diſeaſes the phyſicians call new, which invade whole countries, and ſometimes greater portions of the earth, and laſt very many years, if not ſome ages, before they become extinct.

I ſhall mention but two ſuſpicions more, about the eſtabliſh'd laws and cuſtoms of nature. The firſt is, that I doubt thoſe thought the grand rules, whereby things corporeal are tranſacted; and which ſuppoſe the conſtancy of the preſent fabric of the world, and a regular courſe of things, are not altogether ſo uniformly comply'd with, as we preſume; at leaſt, as to the lines, according to which, the great mundane bodies move, and the boundaries of their motions. For what reaſon the wiſe author of nature pleas'd to permit, that

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that ſhe ſhould be ſometimes, as it were, over-ruled by the exorbitant motions of bodies, I muſt not, in this place, enquire: but, when I conſider the nature of brute matter, and the vaſtneſs of the bodies that make up the world; the ſtrange variety of thoſe bodies which the earth comprizes, and others of them may well be preſum'd to contain; and when I, likewiſe, conſider the fluidity of that vaſt interſtellar part of the world, wherein theſe globes ſwim; I cannot but ſuſpect, there may be leſs of accuracy, and of conſtant regularity, than we have been taught to believe, in the ſtructure of the univerſe. And, to paſs by the irregular motion of the ſun, whence, by the obſervation of the exacteſt aſtronomers, natural days are not all of equal length; this bright luminary, from time to time, not only vomits out great quantities of opake matter, call'd his ſpots, ſome of them bigger, perhaps, than *Europe*, or *Aſia*, but has had almoſt his whole face ſo darkened with them, that, for a year together, he ſuffer'd, as it were, an eclipſe. Add to this, the comets, their number, vaſtneſs, duration, odd motions, and other phenomena; and 'twill appear, that even in the celeſtial part of the world, all is not ſo regular and unvariable, as men have been made to believe. PHYSICS.

I might here declare, that with regard to certain black and white clouds, ſaid to move as regularly in the antarctic hemiſphere, as the neighbouring ſtars themſelves, I have been aſſur'd, by the captain of an *Eaſt-India* ſhip, who lately ventur'd upon unfrequented parts of the ſouth-ſea, that he had often ſeen, in the ſouthern hemiſphere, in the complement of the circle of the milky-way, two or three places appearing like clouds that moved with the white part of the circle, regularly about the earth in 24 hours. But, by his account, I ſuſpect, that the black clouds, ſaid to appear in this quarter, are no more than a kind of perforations, or parts of the azure ſky in the milky-way; for, the colour of them, he ſaid, was not black, but a deep blue. The white clouds, called, alſo, the *Magellanic* clouds, he ſaid, he had often ſeen towards the ſouth-pole, moving about it in 24 hours; and that he began to diſcover them in about 18° ſouth latitude; that they were really white, and three in number, tho' two of them be near each other; the greateſt lying far from the ſouth-pole; but the other, not many degrees more remote than the conſpicuous ſtar, ſaid to be neareſt the ſame pole; that is, about 11° diſtant from it; tho' there is, alſo, ſaid to be one of the fifth magnitude, not 3° diſtant therefrom. But, perhaps, theſe ſuppoſed clouds, if view'd thro' a good teleſcope, would appear to be conſtellations of ſmall ſtars, ſingly inviſible, like thoſe in the galaxy, the belt of *Orion*, &c.

On the other hand, we may, perhaps, take ſuch things for exorbitances and deviations from the ſettled courſe of nature, as, if long and attentively obſerv'd, will be periodical phenomena of very long intervals. But, becauſe men have not ſufficient ſkill, and curioſity to obſerve them, nor a life long enough to be able to take notice of a competent number of them, they readily conclude them to be but accidental extravagancies, that ſpring not from any ſettled, and durable cauſes. For, the world, like a great animal,

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PHYSICS. mal, producing ſome effects but at determinate ſeaſons; if the firſt man had lived but one year in the world, he would, perhaps, have thought the bloſſoming of trees in the ſpring, and their bearing fruit in the ſummer, accidental; and have look'd upon an eclipſe of the ſun, as a prodigy of nature; obſerving, that though at every new moon, the ſun and ſhe came very near together; yet neither before, nor after, was there any ſuch terrible phenomenon conſequent thereupon. And we ourſelves may eaſily remember what ſtrange conjectures we had of the ſeveral various appearances of *Saturn*, for ſeveral years after our teleſcopes firſt diſcover'd them.

But moſt remarkable is that celeſtial phenomenon, afforded us by the emerging, diſappearing, and re-appearing ſtars of this age, which have been obſerv'd in the girdle of *Andromeda*, and in, or about the ſwan's breaſt; and, eſpecially that, which having, about 25 years ago, appear'd for a while, in the whale's neck, among the fixed ones, and afterwards, by degrees, diſappear'd, was look'd upon, by the aſtronomers of that time, who did not out-live it, as a comet: but, afterwards, an ingenious *Engliſh* gentleman, of my acquaintance, having obſerv'd here, the return of the like phenomenon, in the ſame part of the heavens, it caus'd much wonder: ſince when, the famous *Bullialdus*, and others, have taken notice of it, in the ſame place. Now, theſe obſervations, and eſpecially, the laſt diſappearance of a ſtar, judg'd to have been plac'd among the fixed ones, and eſtimated to be of the 4*th* magnitude, have ſomewhat confirm'd me in the ſuſpicion I am now upon. For, if this, and the other new ſtars, continue to return, periodically, to the ſame part of the heavens, where they have been already ſeen, as, at leaſt, in this its gradual increaſe, after it began to ſhew itſelf, and decreaſe afterwards, ſeem to promiſe; then I may, with more probability than before, ſuſpect that there are vortices beyond the ſurface of what we call the firmament: which ſuſpicion, if true, would much diſcredit the hypotheſis we now have about the ſyſtem of the world; and favour what I conjectur'd, as poſſible, about periodical phenomena. However, if either the new ſtar, without departing from its place, be only ſometimes, by degrees, over-ſpread, and hid by ſpots, like thoſe of the ſun, which are afterwards, alſo, diſſipated; or if it have a dark hemiſphere, as well as a light one; or rather a greater part of its globe obſcure, than luminous, as *Bullialdus* ingeniouſly conjectures, and by turning ſlowly about its own axis, ſometimes obverts to our eyes its luminous, and ſometimes its dark part; there will be reaſon to queſtion, the great uniformity imagin'd in the celeſtial bodies, and motions; and to countenance what has been propos'd about periodical mutations in the mundane globes; eſpecially ſince theſe phenomena argue, that even thoſe ſtars we call fix'd, and have look'd upon as invariable, are ſubject to mutations great enough to be taken notice of by our naked eyes, at ſo immenſe a diſtance.

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Fundamental Experiment

MADE WITH

N I T R E.

SAlt-petre, either in its rudiments, or diſguizes, is to be found in ſo great a number of compound bodies, that it ſeems to be the moſt univerſal of ſalts; and, conſequently deſerves the ſtricteſt examination, in order to diſcover the nature of other bodies, and to improve ſeveral parts of natural philoſophy.

Having by the uſual way of ſolution, filtration, and coagulation, reduced common nitre into cryſtals, we put four ounces of it, thus purified, into a ſtrong new crucible; wherein we melted it into a limpid liquor, and, whilſt it was in fuſion, caſt into it a ſmall live coal, which preſently kindled it, and made it boil, hiſs, and flaſh for ſome time: after this, we caſt in another glowing coal, which made it fulminate a-freſh; and, after that, a third, and a fourth; and ſo continued the operation, till the nitre would neither fulminate, nor be kindled any more. Then we continued to keep it in a ſtrong fire for above a quarter of an hour, that if any volatile part ſhould yet remain, it might be forced off. And now taking out the crucible, and breaking it, whilſt it was hot, we divided the remaining fixed nitre, into two equal parts, and diſſolved one in as much fair water as would juſt ſuffice for that purpoſe; then dropp'd on it ſpirit of ſalt-petre, till the ebullition ceas'd; and, after filtration, expos'd it in an open vial to the air: and to the other portion, not diſſolved, we dropp'd, likewiſe, of the ſame ſpirit, till the hiſſing and ebullition wholly ceas'd; and then expoſed this, alſo, to the air, with the former. The event was, that the mixture wherein we employ'd fair water, ſhot, in a few hours, to the lower-part of the ſides of the glaſs, ſome ſaline particles, which ſeem'd, by their form, to be ſalt-petre; amongſt which, nevertheleſs, there appear'd to ſwim very little grains of ſome other kind of ſalt. The cryſtals were, the next day, taken out, being by that time, grown ſomewhat larger, and more numerous; and, upon trial, they diſcover'd themſelves to be truly nitrous, both by their burn-

The experiment.

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PHYSICS. burning and ſhape. The figure of the cryſtals of refin'd, unanalyz'd nitre, I found, upon examination, to be not cylindrical, but each appear'd to have ſix flat ſides, of unequal breadth; any two of the oppoſite ones, being commonly parallel. The remaining liquor, being pour'd into an open glaſs, and left in the ſame window, continued for five or ſix days without any conſiderable alteration; but, at the end of that time, there began to appear very fine cryſtalline *Stiriæ* of petre, which gradually grew more numerous for a fortnight longer. A great part of the other mixture, wherein no water was employ'd, ſubſided in the form of ſalt, over which there ſwam a little liquor, that ſeem'd to keep the ſubſiding particles from congealing into one coherent maſs; and part of this ſalt, being taken out, and dried in the air, appear'd not very regularly figur'd, yet reſembled the ſhape of ſalt-petre; and, caſt on a quick coal, imitated the deflagration proper to nitre. The remaining part of this ſalt, together with the liquor ſwimming upon it, we kept, for about a month, in the open air, without diſcerning any change, till towards the latter-end of that time, when it coagulated into ſmall ſaline maſſes, whoſe figures were not diſcernible; and therefore, diſſolving the whole in a little fair water, and filtring it, we found after evaporation, about one half of the ſalt ſhot into fine cryſtals, figured like thoſe of petre, tho' ſomewhat different in taſte, but burning upon a live coal like them: and the remaining half of this ſolution being haſtily exhaled, let fall its ſalt in a figure not reducible either to that of ſalt-petre, or of any other determinate kind.

Obſervations upon making the experiment. To render this experiment the clearer, let it be obſerv'd, (1.) That a freſh coal is not to be thrown in, till the detonation, occaſion'd by the former, be almoſt ended, unleſs the matter blows that too ſoon out of the crucible. (2.) That the ſpirit of nitre requiſite to be dropp'd on, amounts not quite to ſo great a weight as the ſalt-petre loſes in its detonation. (3.) That the fixed nitre, thus made, differs but very little from vulgar ſalt of tartar, in lixiviate taſte, in its aptneſs to attract the moiſture of the air, and its other more obvious qualities; only, as ſalt of tartar is white, this was of a deep colour, betwixt blue and green, which yet, upon the affuſion of the ſpirit of nitre, vaniſh'd; tho' ſome ſort of calcin'd nitre will, of itſelf, obſtinately retain that colour.

But, for a more expeditious way to re-produce nitre, we run its fixed ſalt *per deliquium*, which, after filtration, immediately ſhot, with the ſpirit of nitre, into true nitrous cryſtals: but becauſe, in dry weather, this ſalt is long in running, we have done the ſame thing with a ſolution of fixed nitre, fair water, and ſome portion of the ſpirit. And leſt it ſhould be ſuſpected, that theſe cryſtals proceeded from ſome particles of nitre, yet lurking in the ſalt after fixation, we have produced the ſame from common pot-aſhes, and *Aqua fortis*.

Deductions from the experiment, as to the cauſe of heat and cold. Hence we ſee, that motion, figure, and diſpoſition of parts, with the like primary and mechanical properties of matter, ſuffice to produce thoſe more ſecondary affections of bodies, which are called ſenſible qualities. And to begin with heat and cold; it is commonly ſuppoſed, that

ſalt

ſalt-petre is one of the coldeſt bodies; yet the parts of it, *viz.* its ſpirit and fixed ſalt, put together, immediately agitate each other, with vehemence, and produce a great heat; as if that quality were nothing but a various, and briſk motion of the minute particles of bodies: for the heat continued as long as this confuſed agitation laſted, and with that agitation it increaſed, or abated; and at length, when the motion ceaſed, the heat, alſo, vaniſhed. PHYSICS.

Upon the mixture of the two above-mention'd liquors, there was, alſo, produced a very audible ſound, not unlike that of a live coal in water; and this hiſſing was accompanied with an effervescence and boiling, till the bubbles were ready to flow over the veſſel. The ſound ſeem'd to proceed from the ſudden and ſmart percuſſions of the air, made by the ſwift and irregular motion of the particles of the liquors; for it increaſed and grew faint in proportion to their ebullition. And ſuch a kind of noiſe, but much louder, was produced by caſting a live coal upon the ſalt-petre. What intereſt ſuch a ſmartneſs in ſtriking the air hath in the production of ſound, may, in ſome meaſure, appear by the motion of a bullet, and that of a wand, which produce no ſound, if they ſlowly paſs thro' it; but if the one ſmartly ſtrike the air, and the other be ſhot out of a gun, the celerity of their percuſſions puts it into an undulating motion, which produces a conſiderable ſound. This noiſe ended long before the heat; to produce the latter whereof, ſuch an inteſtine tumult of the parts of many bodies will ſuffice, which is yet unable to produce a ſound: as we ſee in amber, or good hard wax, heated by rubbing; and in many liquors, that retain a conſiderable degree of heat long after the expiration of the noiſe they made in boiling. *Sounds.*

The diverſification of colours is obſervable in many inſtances, as well as in this experiment. And the like change we have, ſometimes, obſerved in fixed nitre, upon leaving it in the moiſt air. The copious fumes ariſing from the mixture, would make the unfill'd part of the glaſs of a reddiſh colour; which is not more odd, than that thoſe of diſtill'd ſoot ſhould appear as white as milk. A ſublimation, likewiſe, of ſal-armoniac, and antimony, exhibits a ſtrange variety of colours: but, in making a nitre from pure ſalt of tartar, and *Aqua fortis*, there aroſe a deep green colour. And, nitre itſelf, yields, in diſtillation, blood-red fumes, which fall again into a liquor that manifeſts no redneſs at all. *Colours.*

Upon the mixture of theſe two liquors, there is, alſo, produced a very ſtrong and offenſive ſmell. But tho' the ſpirit of nitre hath an ungrateful odour, of itſelf, yet it is made much more offenſive, by being poured on its own fixed ſalt. The odour of the fixed nitre is very languid; but that which it diſcovers, when diſſolved in a little hot water, is wholly different from the offenſive ſcent of the other; being of kin to that of alkalizate ſalts. And yet the ſalt-petre, from which ſuch differently-ſcented bodies proceed, and which may again emerge from the coalition of them, has no ſmell at all. *Odours.*

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PHYSICS. Again, the taſtes of theſe two bodies, are as different as any of their other qualities: the fixed nitre has as ſtrong a taſte of ſalt of tartar, as the ſpirit has of diſtill'd vinegar; yet theſe two bodies both ſpring from, and unite into ſalt-petre, which betrays upon the tongue, no heat, nor corroſiveneſs. And tho' the renew'd ſalt-petre had, at firſt, a taſte more ſharp than ordinary nitre, yet that pungency may, probably, have proceeded from ſome acid particles of the ſpirit, not duly incorporated with the nitrous parts.

Taſtes.

Inflammability. Farther, this experiment makes it queſtionable, whether inflammability ſtrictly requires a ſulphureous ingredient; and whether it may not reſult from ſuch a contrivance of parts, as diſpoſes them to be put in motion by the adventitious corpuſcles of another body, ſo as to exhibit what we call flame*. How violent a heat is producible upon ſuch an account as this, may appear by a mixture of filings of iron, and ſpirit of nitre; which will preſently begin to penetrate the metal, disjoin, ſhake aſunder, and ſcatter its parts, with great rapidity, upon which a ſtrong heat enſues; tho' the ſame ſpirit will calmly run camphire into an oil, without manifeſting any conflict.

Our experiment, alſo, informs us, that ſalt-petre may be produced by the coalition of two bodies, which are neither of them inflammable. 'Tis obſervable, that upon caſting nitre on a glowing coal, or upon the caſting a glowing coal into that when melted, the nitre will immediately take fire, and flaſh out into bluiſh flames; but, if the ſame nitre be placed in a crucible, which ſhall, by degrees, be made glowing hot, the ſalt will be thereby melted, but not kindled.

Fluidity, and fixedneſs. It may alſo deſerve enquiry, whence ſalt-petre, which when committed to diſtillation, is very well dried, ſends over ſpirits into the receiver, that do not, as ſal-armoniac, and ſome other bodies, diſtill'd with the like heat and veſſels, adhere in the form of ſublimate, but fall into a liquor that coagulates not in the cold. The like enquiry may be made, concerning the fluidity of the diſtill'd ſpirits of decrepitated ſalt, calcin'd vitriol, &c. which ſeem to have been deſtitute of moiſture, when committed to diſtillation.

Volatility, and fixedneſs. Again, tho' good ſpirit of nitre waſtes itſelf in a ſenſible exhalation, yet, when it is once re-united to its own fixed ſalt, it emits no ſuch ſteam, tho' long kept, near a conſiderable fire; which ſhews how the more active parts may be entangled, and hindred from eſcaping by thoſe which are more ſluggiſh. Farther, upon dropping the acid ſpirit into the alkalizate liquor you may plainly diſcern the ſaline particles toſs one another to a great height, into the air, whence moſt of them fall back into the veſſel, like a thick ſhower of little

* "Do not, (ſays Sir *Iſaac Newton*) all "fix'd bodies, when heated beyond a certain "degree, emit light, and ſhine? and, is not "this emiſſion perform'd by the vibrating mo"tions of their parts? And, do not all-bodies, "which abound with terreſtrial parts, and eſ"pecially with ſulphureous ones, emit light "as often as theſe parts are ſufficiently agi"tated, whether that agitation be made by "heat, or by friction, or percuſſion, or pu"trefaction, or by any vital motion, or any o"ther cauſe? See *Newton. Optic.* p. 314—"319.

drops.

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drops. And that theſe particles are ſaline, is manifeſt from thoſe which fall on the outſide of the glaſs, ſettling into little grains of ſalt. And that there is a very briſk agitation in the particles of the ſpirit of nitre, appears from hence; that upon pouring *Aqua fortis*, whoſe active part is little elſe than ſpirit of nitre, upon ſalt of tartar in fair water, the acid ſpirit will ſever the particles of ſalt with ſuch impetuoſity, that the bubbles produced upon their conflict, aſcending in ſwarms, make them appear like ſo many little riſing ſprings. PHYSICS.

The action of menſtruums.

And it may be uſeful to obſerve the difference betwixt thoſe active parts of a body, which are of differing natures, when entangled with others in the texture of a concrete; and the ſame particles, when ſet at liberty: for tho' in the intire body of ſalt-petre, its ingredients act but very languidly, yet we ſee with how great an activity both the acid ſpirit, and the fixed ſalt, are ſeparately endow'd. And we may yet farther obſerve, that it is not barely an activity of the particles of ſaline liquors, which enables them to produce their particular effects; for, to the production of ſome of theſe there ſeems requiſite, beſides a modification of their motion, a determinate figure of the corpuſcles, anſwerable to that of the pores of the body, to be diſſolved by them: thus ſpirit of nitre corrodes ſilver, but not gold; tho' when its particles are aſſociated with thoſe of ſal-armoniac, whereby it acquires a new figure, and, perhaps, a different motion, it will readily diſſolve gold. And the liquor of fixed nitre will, for the ſame reaſon, diſſolve ſuch ſulphureous bodies as the acid ſpirit will not touch. Nay, there may be liquors, which will not diſſolve ſome bodies, unleſs the motion, or activity of their particles, be allay'd, or modified by the mixture of fair water, or ſuch unactive vehicles.

The different virtues of intire bodies, and their ſeparate ingredients.

Our experiment farther ſhews us, the unwarineſs of thoſe chymiſts, who confidently aſcribe to each of the ingredients or principles of a concrete, the virtues and properties of the intire body; for, herein we may obſerve, that when ſalt-petre is diſtill'd, the volatile liquor, and fixed ſalt, into which it is reduced by the fire, are endowed with properties exceeding different both from each other, and from thoſe of the undiſſipated concrete: for, the ſpirit of nitre is a kind of mineral vinegar, and poſſeſſes the common qualities to be met with in acid ſpirits; tho' the fixed nitre is of an alkalizate nature, and participates of the qualities generally belonging to lixiviate ſalts. And ſalt-petre, itſelf, is diſcriminated by diſtinct properties, both from thoſe ſalts which are eminently acid, as alum, vitriol, ſal gem, *&c.* and from thoſe that are properly alkalizate, as ſalt of tartar, and pot-aſhes. Accordingly, we may eaſily obſerve a vaſt diſparity in the effects and operations of theſe three bodies. For ſeveral, if not all of thoſe mineral ones which *Aqua fortis* will, by corroding, diſſolve, the ſolution of fixed nitre precipitates; and ſeveral, if not all, of thoſe ſulphureous bodies, which the ſolution of fixed nitre diſſolves, the acid ſpirit of ſalt-petre will precipitate. Thus, if into a ſcarlet tincture of brazil in fair water, we pour a little ſpirit of nitre, the liquor will in a moment change its redneſs for a yellow; which, by pouring on it a little of the ſolution of fixed nitre, may be again rais'd to a ſanguine colour, ſometimes paler,

PHYSICS. paler, and ſometimes deeper than the firſt: whereas, a ſolution of ſalt-petre, pour'd into either the red, or the yellow tincture, has not been diſcern'd to produce any ſenſible effect. And as ſalt-petre is partly fixed, and partly volatile, the acid ingredients of it are wholly volatile, and the alkalizate fixed.

The generation of nitre. We may, alſo, from our experiment take occaſion to enquire, whether the air doth not contribute to the artificial production of ſalt-petre; for the ſalt, which was leiſurely permitted to ſhoot in the liquor, expoſed to the open air, ſhot into more fair and large *Stiriæ*, than thoſe obtain'd from the remaining part of the ſame liquor, by a more haſty evaporation. And when we poured *Aqua fortis* on a ſtrong ſolution of ſalt of tartar, till no farther effervescence was diſcernible, it would not ſhoot into ſo fair cryſtals of petre, till it had been long expoſed to the open air. But whether the air really contributes any thing, either to the production, or figuration of ſalt-petre, in our experiment, I dare not yet determine; becauſe, firſt, the figuration ſeems not owing ſo much to the proper efficiency of the air, as to the conveniency of a competent vehicle for the cryſtals to move in, and conform themſelves to that figure which is moſt natural to them. For the fixed nitre, which was not diſſolved in water, before the affuſion of the acid ſpirit, did not ſhoot into the uſual form of cryſtals of petre, but remain'd a kind of nitrous powder; being neceſſitated, for want of room, to make an over-haſty coalition; and, therefore, differ'd from thoſe, into which the ſaline corpuſcles would have diſpoſed themſelves, had they been allow'd a competency of vehicle, and time. And, ſecondly, I forgot to try, whether part of that liquor, which ſhot into cryſtals in an open glaſs, expoſed to the air, would not have done the like, if it had been left quiet, as long as the other was, tho' in a veſſel accurately ſtopp'd. But whatever the air hath to do in this experiment, we have known ſuch changes made in ſome ſaline concretes, chiefly by help of the open air, as very few would be apt to imagine.

The forms of bodies. But if, upon farther tryal, it appears, that the whole body of ſalt-petre, after diſtillation, may be adequately re-united into ſalt-petre, equi-ponderant to its original ſelf, this will afford us a noble inſtance to ſhew, that what is commonly call'd the form of a concrete, which gives it its being and denomination, and from whence all its qualities are ſuppoſed, in the vulgar philoſophy, to flow, may be, in ſome bodies, but a modification of the matter they conſiſt of; whoſe parts by being particularly diſpoſed, with relation to each other, conſtitute a determinate kind of body, endowed with peculiar properties; whereas, if the ſame parts were otherwiſe diſpoſed, they would conſtitute other bodies of very differing natures from that of the concrete, whoſe parts they formerly were; and which may again be produc'd after its diſſipation and ſeeming deſtruction, by the re-union of the ſame component particles, aſſociated according to their former diſpoſition. The renewal of an analyzed body, accurately, and really perform'd, may give great light to many particulars in philoſophy. And tho' in this experiment of ſalt-petre, even as we have already made it, there is not an exact

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exact and adequate restoration, it is yet not far from being a real one; the dissipated parts of the concrete truly re-uniting into a body of the same nature with the former, though not altogether of the same bulk*. It may be requisite to observe, that salt-petre is no very compounded body; and therefore others, which consist of more numerous ingredients, cannot be safely judg'd of by what is possible to be performed on that: for, even wine, we see, when its spirit is, by distillation, drawn from it, will not, by the re-union of its constituent liquors, be reduced to its pristine nature; because the workmanship of nature, in the disposition of the parts, was too elaborate to be repaired by the bare apposition of them to each other again: besides, in the act of dissociation, even by the gentlest fire, some active particles will, perhaps, undiscernibly vanish, whose presence was requisite to preserve the concrete under its determinate form; as we see wine degenerate into vinegar, upon the avolation of some subtile sulphureous spirits, not to be perceiv'd by any sensible diminution of the liquor. And, certainly, there is so artificial a contrivance of particles requisite to the constitution of the organical parts of living bodies, that it will be scarce possible for human art to imitate those productions: and, therefore, I wonder not that the story of the *Phœnix* reviving out of her own ashes, should pass for a fiction. And if what *Kircher* relates, as an eye-witness of the re-production of shell-fishes, near a lake in the *Sicilian* promontory *Paloro*, by watering their broken bodies with salt-water, in the spring, be strictly true; it seems much more improbable, that such changes should be bare restorations, than that they should be new productions, made by some seminal particles, lurking in the destroy'd body, and afterwards excited by a genial heat to act upon, and organize a disposed matter, according to the exigencies of its own nature. For that, in some bodies, the seminal particles may, a-while, survive the seeming destruction of life, is not without example. And, in *Kircher*'s story it is to be observ'd, that the restored animals were but shell-fish, in whose viscous substance, the spirits, and prolific parts, are, probably, more diffused and preserved: and we may add, that in such fish, the mechanical contrivance is but very plain and slight, compared with that of more perfect animals.

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The last observable, we shall at present take notice of, in our experiment, is, that some chymical remedies may be too rashly rejected by physicians, because corrosive liquors have been employ'd in their preparation; on a conjecture, that they can never be so exquisitely wash'd off, but that some of the salts must adhere to the medicine, and display their nature in the body. 'Tis true, indeed, that many ignorant chymists, either employ corrosives without any necessity, or neglect sufficiently to free their medicines from the corroding salts, wherewith they were prepared; for, fre-

Corrosiveness and corrosibility.

* Mr. *Homberg* having, with great care and accuracy, resolved the body of common sulphur into an acid salt, a bituminous substance, and an earth mix'd with a few metalline parts, M. *Geoffroy*, re-composed these principles into true, inflammable sulphur, only substituting oil of tartar for the latter. *Memoir. de l'Academ.* A. 1703. p. 376. *Ed. Amst.*

quent

PHYSICS. quent ablutions will not always suffice for this purpose. But there may be several bodies, which quite alter the nature of the acid salts, employed to prepare them; by occasioning those salts to degenerate into another nature, upon the very act of corroding; or else, by so associating their own salts with those of the dissolving menstruum, that, from the coalition of both, there arises a third body differing in qualities from either. Thus in our experiment we find, the spirit of nitre, which is much more sharp than distill'd vinegar, and the fixed nitre, which is caustic, do, by their mutual action, work themselves into salt-petre; which is far from having any fretting quality, and may be safely taken inwardly, in a much greater dose than either of its ingredients. And how much corrosive salts will dulcify themselves by corroding some bodies, may easily be tried, by pouring distill'd vinegar, or moderate spirit of vitriol, upon a competent proportion of any testaceous substance. It were, therefore, worth while, in every preparation, where corrosive liquors are employ'd, to consider the distinct nature of the bodies to be wrought upon; or to consult experience, whether or no the acid menstruum communicates to the concrete any particles capable of retaining their fretting quality, after the operation is ended; or, whether the salts do not spend themselves in the act of corroding, so as to become unable to corrode any farther; or, whether the menstruum does not, in the body to be corroded, meet with some such saline particles, as may, with it, constitute a new and inoffensive substance; as when spirit of vinegar, by corroding calcined lead, is turn'd with it into a salt, not of an acid, but of a saccharine taste. In the former of these cases, the medicine may prove dangerous, unless it be, after the solution, exquisitely dulcified; but, in the two latter, the remedies may, in spite of the corrosiveness of the menstrua, be safe and innocent: for it matters not how sharp the sever'd ingredients of a remedy are, provided the remedy itself, resulting from them, be not so. It is objected, that in several of these remedies, the corrosive salts are not really destroy'd, but only disguized; because, by distillation, it is possible to separate the liquors used about them, as corrosive as ever. To this it may be easily reply'd, that it little concerns us to be sure that out of the medicines we take, the fire cannot separate corrosive salts; provided we are duly satisfied, that no such separation can be made by the heat, or juices of a human body. And therefore, though it has been affirm'd, that *Tartarum Vitriolatum* would, with a strong fire, part with much of the oil of vitriol, which concurr'd to its production; yet our best physicians scruple not to give it internally in several distempers. And, to conclude, we clearly see, that salt-petre is frequently, and safely given inwardly; though the salt which makes even *Aqua fortis* so corrosive, be the principal ingredient of it, and may, by distillation, be driven from it.

THE

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THE ORIGIN OF Fluidity and Firmneſs.

SECT. I.

WHether fluidity and firmneſs be not rather ſtates, than qualities, we ſhall not here examine: but, as they are the moſt general properties of bodies, it is well worth our while to find out more ſatisfactory explanations of them, than we have receiv'd from the ſchools.

A body ſeems to be fluid, by conſiſting of corpuſcles touching one another only in ſome parts of their ſurfaces; whence, by reaſon of the numerous ſpaces betwixt them, they eaſily glide along each other, till they meet with ſome reſiſting body, to whoſe internal ſurface they exquiſitely accommodate themſelves*. *A fluid, what?*

It is probable that, in many liquors, the little ſurfaces of the component particles are ſpherical, ſmooth, and ſlippery; which will greatly facilitate the rolling of the corpuſcles among themſelves, and, conſequently, promote the fluidity of the body they compoſe. But, there are ſeveral other figures, which may make the little bodies endow'd with them, voluble enough to conſtitute a fluid ſubſtance. And the other qualities to be met with in ſome liquid ſubſtances, as water, and oil, ſeem to argue their parts to be otherwiſe ſhaped; and thoſe fluids which are not liquors, as air and fire, ſeem compoſed of particles, not all of them round, but of very various, and, ſometimes of very irregular figures; yet ſuch bodies deſerve to be called fluid. It is not neceſſary to the fluidity of a body, that the corpuſcles it conſiſts of, ſhou'd be crowded as cloſe together as they are in water, and others,

* Sir *Iſaac Newton* defines a fluid to be that body whoſe parts give way to any impreſs'd force; and which by giving way, are eaſily moved among another. *Newton. Princip.* p. 260.

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PHYSICS. commonly look'd upon as the only liquors. For, tho' a parcel of matter no bigger than a grain of corn, being rarified into ſmoke, will poſſeſs a much greater ſpace, than it did before; and tho', if a body be farther rarified into flame, its expanſion will be yet much greater; yet both ſmoke and flame, may be made to appear like liquors. Thus in blowing a mouthful of the former through a glaſs pipe, to fill it, and, afterwards, ſtopping the other end, on any inclination, it will ſettle, by degrees, to a level ſuperficies, parallel to the horizon. And, as for the latter, I have ſo prepared copper, with ſal-armoniac, that a few ſmall grains of it, put into the wiek of a burning candle, would give a very durable flame, perfectly green; which kept diſtinct from that of the candle, as if there had been ſome inviſible partition between them.

The requiſites to fluidity, viz. ſmallneſs of parts.

The conditions of a fluid ſeem to be, chiefly, theſe. Firſt, a ſmallneſs of the component particles; for bulk is apt to render them too heavy, to give way to thoſe cauſes which make fluids move ſo freely among themſelves. Lead, quick-ſilver, and, even gold, though, whilſt they are of a ſenſible bulk, they will readily ſink to the bottom of *Aqua regis*, or any other ſuch liquor; yet, when the menſtruum has corroded them into very *minute* parts, they grow ſo much more capable of agitation than before, as to be freely carried every way: nay, ponderous bodies may, by diviſion, be render'd ſo light as to become ingredients even of diſtill'd liquors. Butter of antimony, though a very limpid liquor, will, with fair water, precipitate a heavy, white calx, reducible to glaſs.

But to ſhew yet more particularly, that bulky bodies are unfit to conſtitute fluid ones, we may obſerve how nature, as well as art, in order to render them ſuch, makes a comminution of them; as in the ſtomachs of dogs, to reduce bones into chyle, by ſome peculiar fluid; in imitation of which, I made a certain liquor, whereby I have, in a ſhort time, and without fire, diſſociated the parts of bread, fleſh, fruit, *&c.* and reduced them to the conſiſtence of fluids. Nor is a great quantity of an appropriated liquor requiſite to the digeſtion of the aliment. Common water, the uſual drink of moſt animals, as particularly dogs, wolves, *&c.* appears, of itſelf, very unfit to diſſolve bones, *&c.* even by boiling; and many ſorts of creatures, particularly camels, may, even in hot climates, be brought to travel, for many days, without drinking. I am familiarly acquainted with a gentleman, who uſually drinks but once in ſeveral days; and then, no exceſſive draught: and once, in particular, he continued about nine days, without taking in, or requiring any liquor; and might have continued much longer in that ſtate, had he not diſtemper'd himſelf by hard ſtudy; and, even then, one ſmall draught ſerv'd him for about four days longer. This gentleman, too, is in the flower of his age, and of a florid and ſanguine complexion; he ſweats freely, eats as other men; and his urine in quantity, is like that of others of his age and temper. We ſee, likewiſe, that fuſion makes metals fluid; which cannot be done whilſt they continue in maſſes of any ſenſible bulk: and even melted metals may have their fluidity increas'd, by a yet farther comminution of their parts.

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And as to the enquiry, whence it happens, that in the diſtillation of dry ſaline bodies, there will be obtain'd a perfect liquor, it may, indeed, be ſaid, that in ſeveral dry bodies, ſuch as hartſhorn, wood, and bones, the fire does no more than ſeparate the aqueous parts from the others, and bring them together into the receiver; but this doth not reach the difficulty, becauſe the thing holds in bodies already calcined, ſuch as the calx of vitriol, fluxed ſea-ſalt, *&c.* which yet afford liquors, tho' their aqueous, and looſer parts, have been driven away by a ſtrong fire, before they were expoſed to diſtillation. Perhaps, then, the vehement agitation produced by heat, both divides ſuch bodies into minute corpuſcles, and drives them over into the receiver; where, loſing their former agitation, they are reduced into a liquor, chiefly becauſe the fire has rent the concrete into parts, which, by their extreme minuteneſs, by their figure, or by both together, are fitted to be ſo eaſily moved, that the uſual agitation of the air, propagated thereto, or the ſame cauſe that gives the air its agitation, is able to keep them fluid. PHYSICS.

Viewing a glaſs of the chymical oil of anniſeeds, that ſtood frozen, by the cold ſeaſon, in a window, I immediately melted it, poured a particular liquor upon a part of it, placed in another glaſs, and ſuffer'd the reſt to cool in the ſame veſſel that contain'd it before. When this was fully cool'd, I found it again congeal'd, as uſual; but the other continued fluid, both day and night, and in ſeveral changes of weather; and ſtill remains at the bottom of the menſtruum a clear oil diſtinct from it, though I have often ſhaken them together. And having ſlowly evaporated good clear *Venice* turpentine, till the remaining part afforded a fine colophony, I reduced ſome of this tranſparent gum to fine powder, and put a greater proportion of it into pure ſpirit of wine, than the liquor was able to diſſolve, that a quantity of the colophony might remain at the bottom; whereby I obtain'd a ſluggiſh liquor, that continued fluid as long as the menſtruum was left upon it: but, when the glutinous liquor was ſeparated from the menſtruum, it would gradually harden in the air. And whilſt this ſubſtance was fluid, I could not by ſhaking, make it truly or laſtingly unite with the ſpirit of wine.

That, alſo, ſome bodies will be kept fluid, by a much leſs degree of agitation than others require, ſeems probable from hence, that wine will continue a liquor in ſuch a languid warmth of the air, as cannot keep the parts of water moving, but permits them to reſt in the form of ice. And, in cold countries, where wine itſelf congeals, though the more aqueous parts will there, by loſs of motion, be turned into ice, yet the more ſubtile, and ſpirituous, remain unfrozen. And tho' cold may very much condenſe even air, yet, that it hath never been frozen by any degree of cold whatever, ſeems to proceed from the extreme ſmallneſs, and peculiar figure of its parts, giving way to the leaſt agitation.

An ingenious teacher of mathematics, having occaſion to make a compoſition for a new fire-engine, whereof he was to ſhew his Majeſty a trial, mingled divers ingredients in an earthen pot, over kindled coals; but

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PHYSICS. could not, or did not, do it ſo warily, but that the matter took fire, and began to blaze furiouſly; which obliged him to ſtifle the flame as haſtily as he could: and having remov'd the veſſel from the fire, and ſuffer'd it to grow cold, when afterwards he came to look upon it, to ſee if what remain'd might be of any uſe to him, he was ſurprized to find it variouſly and briſkly moved. Wherefore, having ſet it aſide, to be ſure that it might be thoroughly cold, he, after ſome hours, viſited it again, and found it move as before. And, having caſt ſtore of ſeeds upon it, to ſee if the liquor would move them alſo, the bituminous part of it connected them into a kind of thick ſcum, that cover'd moſt of the ſuperficies; but yet left ſome intervals, in which the liquor appear'd, and diſcover'd that it continued its motions. Two days after, the engineer diſcourſing of his fire-work, about which he had advis'd with me before, told me of this odd accident. And alledging that the motion continu'd ſtill, my diffidence, or curioſity, made me engage him to ſend for the pot as it was; partly to be ſure of the matter of fact, and partly to try if the knowledge I had of the ingredients, would afford any hint as to the cauſe of ſo odd an effect; a like to which, in kind, tho' not in degree, I had many years before ſeen, and ſucceſsfully practis'd the way of producing.

The veſſel being come, there appear'd manifeſt ſigns of ſuch a motion as the engineer had aſcribed to it; and therefore I caus'd it to be ſet aſide in a laboratory, where ſome furnaces kept the air conſtantly warm, and did there, and elſewhere, at diſtant times, look heedfully upon it, now and then diſplacing, or quite taking off ſome of the thick ſcum, that too much cover'd the ſurface of it; and by this means, I had the opportunity to take notice of ſeveral phenomena, whereof theſe are the chief.

1. I obſerved, that the motion of this liquor was not only briſk, but very various; ſo that having looſen'd ſome ſmall portions of the ſcum from the reſt, one of them would be carried towards the right-hand, for inſtance, and another towards the left, at the ſame time. 2. Where the liquor came out firſt from under the ſcum, it ſeem'd to move the moſt briſkly, flowing almoſt like a ſtream, whoſe motion upwards had been check'd, and, as it were, reverberated by that incumbent obſtacle. 3. Several motions in this liquor were the more eaſy to be obſerved, becauſe, tho' it were dark, yet it was not uniform, conſiſting, in part, of oily, and bituminous ingredients, which, tho' they ſeemed to have but one common ſuperficies with the reſt of the liquor, yet, by their colours, and vigorous power of reflecting the light, they were eaſily diſtinguiſhable from the reſt. And I often obſerved, that ſome of the unctuous portions of the matter, emerging to the ſurface of the liquor, tho', perhaps, at firſt, one of them would not appear bigger than a pin's head; yet, in moving forwards, it would, at the ſame time, diffuſe itſelf circularly, and make, as it were, a great halo, adorned with the colours of the rain-bow; and ſo very vivid, as afforded a pleaſant, and ſurprizing ſpectacle; theſe phantaſms often nimbly ſucceeding one another, and laſting till they loſt themſelves againſt, or under the thick ſcum. 4. The motions of this odd liquor were not only various, but

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but frequently vortical; to be ſatisfied of which, I ſometimes put ſhort bits of ſtraw, or fragments of ſome ſuch like ſtuff, upon the diſcover'd part of the ſurface of the liquor, by which they were carried towards very diſtant, if not oppoſite parts of the veſſel at the ſame time. But to make the vortical motion more evident, I ſeveral times detached conſiderably large pieces of the thick ſcum from the reſt of the body; and had the pleaſure to ſee them move, both a progreſſive motion in crooked lines, and with a motion about their own middlemoſt parts. All this while the liquor, whoſe parts were thus briſkly moved, was actually cold as to ſenſe. 5. To obſerve what the preſence, or abſence of the free air would do to this liquor, I caus'd many ſpoonfuls of it, with ſome of the ſcum, to be put into a cylindrical glaſs, which, tho' large itſelf, had a neck belonging to it, which was but about the bigneſs of one's thumb, that it might be well ſtopp'd with a cork. But, having by this means, kept the free air from having a full, and immediate contact with the whole ſurface of the mixture, as it had when that mixture lay in the wide-mouth'd veſſel; I could not perceive the liquor to move to and fro; no, not tho' the orifice of the neck were left open: whereas, having, at the ſame time, pour'd ſome of the liquor into a very ſhallow, and wide-mouth'd veſſel, it moved rather more nimbly and variouſly than in the great earthen pot, (which yet was of the ſame ſhape) and ſhewed us many vivid, and ſelf-dilating circles. 6. Tho' the motions of the liquor did not ſeem to be always equally briſk, yet they appear'd to continue manifeſt and various in ſome diverſities of weather, as to cold and heat, and when I look'd on it by candle-light, as well as by day-light. 7. I kept ſome ſpoonfuls of this liquor cloſe ſtopp'd in a vial, and ſo had the opportunity to obſerve, that when I pour'd out the liquor into a wide-mouth'd veſſel, it would move as before, tho' this were done ſome weeks after it had been put up. About the beginning of *June*, that is, about five months, or more, after the liquor was firſt obſerved to move, to gratify the curioſity of a foreign miniſter, and that of ſome other ingenious men then preſent, I caus'd the vial to be brought, and having unſtopp'd it, I pour'd out the liquor in a conveniently ſhap'd veſſel; in which, after we had ſuffer'd it to reſt a-while, they were delightfully ſurprized to ſee it move (tho' not in my opinion quite ſo briſkly as before) very manifeſtly, and variouſly. This incouraged me to think it poſſible, that it might retain ſome motion, though but languid, ſeven or eight weeks after; and accordingly I then look'd upon it again; and having caus'd it to be pour'd into a china cup, it manifeſted, at firſt, a briſk and various motion. But this, after a-while, ſo ſlacken'd, that I began to have ſome ſuſpicion, the motion it was put into by the effuſion, and the firſt contact of the air, might have given it the greateſt part of its agitation; but this was only ſuſpicion.

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To proceed; it is, likewiſe, poſſible, that a ſaline ſpirit may conſiſt of very minute grains of ſalt; for, a ſal-armoniac may be made by ſpirit of urine, and ſpirit of ſalt, as the common ſal-armoniac is with crude ſalt; and the urinous one, as ſtrictly as it here ſeems united to the other, may be readily ſepa-

rated

PHYSICS. rated from it. And, as common *Aqua fortis* may be enabled to diſſolve gold, by the addition of ſpirit of ſalt; ſo common crude ſalt, barely diſſolved in it, will give it the like power of working upon gold; nay, crude nitre, diſſolved in good ſpirit of ſalt, may make it ſerve for an *Aqua regis*. And, the moſt noted perſon in *Holland*, for diſtilling corroſive bodies, affirmed to me, that he had, by uſing brick-duſt, ſand, *&c.* ſometimes brought over almoſt the whole body of ſalt into a liquor; ſo that from a pound, he has eaſily obtain'd no leſs than twelve ounces of a ſpirit, after it had been well rectified. And *Beguinus* teaching the diſtillation of another ſalt, adds, that if you had wrought well, you ſhall get from a pound of the matter, a pound of ſpirit. But becauſe from all theſe liquors, it is poſſible to obtain a portion of phlegm, or water, I leave it to farther trial, whether their fluidity may not, in many caſes, be advanced, by being diluted with water.

A determinate figure of them. We may add, that the ſhapes, as well as the ſizes of bodies, contribute to their fluidity. For tho', in ſal-armoniac, antimony, *&c.* which are by the fire ſublimed into flowers, rather than diſtill'd into liquors, the magnitude of the component corpuſcles may not, perhaps, be a hindrance to the fluidity of the body they conſtitute; yet this ſeems as probably owing to their figure, as to their bulk. I have, by ſlowly diſtilling common olive oil *per ſe*, in a glaſs retort, found about a third part of the oil, which was driven over into the receiver, coagulated into a whitiſh body, almoſt like butter. So that altho' diſtillation can obtain liquors, even from conſiſtent bodies, in this experiment of a concrete naturally fluid, the diſtill'd liquor itſelf proved not to be ſo; of which no cauſe ſeems more obvious, than that the newly acquired ſhape of the diſſipated parts of the oily corpuſcles, makes them unfit for motion, either abſolutely, or, at leaſt, in reſpect of one another, by rendring them leſs pliant, or giving them a figure more eaſy to be entangled with the neighbouring corpuſcles; or elſe, by making their ſurfaces leſs ſmooth and ſlippery than before.

'Tis obſervable of bodies, which conſiſt of incoherent parts, that thoſe, in being poured out, moſt reſemble liquors which are the ſmalleſt; as would appear, upon the emptying of ſeveral ſacks of apples, walnuts, filberts, corn, ſand, and flower. They who make much uſe of whites of eggs, will eaſily reduce thoſe viſcous bodies into a thin and fluid ſubſtance, like water; yet this difference of fluidity, being effected only by long beating, ſeems to be produced but by pulling aſunder the parts, and breaking them into ſhorter, leſs, and, conſequently, more voluble ones. And I have ſeen that jelly, which is ſometimes found on the ground, and call'd by the vulgar a ſtar-ſhoot, reſolved by digeſtion only, into a permanent liquor; which an eminent phyſician, of my acquaintance, extols as a ſpecific, outwardly applied to wens. Goldſmiths obſerve, that when any curious work of ſilver is to be caſt, it is not enough, that the ſilver be barely melted, but it muſt be kept, for a conſiderable time, in ſtrong fuſion: for, if it be too ſoon poured out, the figure it makes, will be blunt; but, if kept a competent time in fuſion, the matter becoming thereby more liquid, will

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will be thin enough to run into the ſmalleſt cavities of the mould, and ſo receive a figuration, even from the moſt delicate of them: whence it is probable, that ſome bodies already fluid, may, by a farther comminution, be made yet more fluid. And, the like increaſe of fluidity may be obſerved in ſome other bodies, eſpecially unctuous ones, as turpentine, oil, *&c.* when heat begins to break, as well as agitate their parts. And, by long digeſtions, with a due degree of heat, there may be made in the parts of many bodies, both vegetable and animal, ſo great a change from the ſtate of conſiſtence, to that of fluidity, as thoſe who content themſelves with ordinary courſes of chymiſtry would not expect. PHYSICS.

Another requiſite to fluidity, is, that there be many vacant ſpaces betwixt the component particles of the body. I need not here require abſolute vacuities; 'tis ſufficient that between the ſolid parts, there be nothing but what will eaſily yield to them, and not reſiſt the freedom of their motions. To illuſtrate this, let it be obſerv'd, that ſnow, which, at its firſt falling, is of a looſe, and open texture, eaſily yields to the impreſſions of the hand; but when, by being ſtrongly compreſs'd, the little icy bodies, of which it conſiſts, are brought into a cloſer order, and many of them thruſt into the little ſpaces, before poſſeſs'd only by the yielding air, they will not give way to the motions of the hand, as before, but compoſe a hard and reſiſting body. However, the exiſtence of vacant ſpaces, or ſome yielding matter about the corpuſcles of a fluid body, ſeems requiſite, only as it obviates that impediment to their motion, which exquiſite fulneſs might prove. And tho' in ſuch bodies as water, wine, oil, quick-ſilver, *&c.* this condition may take place, yet it is not abſurd to queſtion, whether there may be no portion of matter, conſiſting of parts ſo minute, and ſo agitated, as inceſſantly to change places among themſelves, and thereby conſtitute a very fluid body, without any vacuities, receptacles, or yielding matter about them, unleſs on the external parts of thoſe, which, from time to time, happen to be at the ſurface. *Vacuity.*

But the laſt, and chief condition of a fluid body is, that the particles of which it conſiſts, be agitated variouſly, and a-part, by their own innate motion; or by ſome thinner ſubſtance, which ſhall toſs them about in its paſſage thro' them. For, this ſeems to be the principal difference betwixt ſolid ice, and fluid water, that in the one the parts being at reſt, reſiſt thoſe endeavours of our fingers to diſplace them, to which, in the other, the parts being already in motion, eaſily give way. For, whereas in the ice, every part actually at reſt, muſt, by the law of nature, continue ſo, till it be put out of it by an external force, able to ſurmount its reſiſtance, to a change of its preſent ſtate; in water, each corpuſcle being actually moved, we need not begin, or produce a new motion in it, but only direct that which it has already. From this agitation of the parts of fluids, thoſe minute bodies, to continue their motion, glide ſometimes over, ſometimes under, and ſometimes by the ſides of one another. And hence appears the cauſe of ſoftneſs in fluid bodies, that is, their yielding to the touch; for, the particles which compoſe them, being ſmall, incoherent, and variouſly moved, *Agitation.*

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PHYSICS. moved, it is eaſy to thruſt them out of thoſe places, which, being already in motion, they were diſpoſed to quit; eſpecially when there are vacant ſpaces at hand, ready to admit them, as ſoon as they are diſplaced. And hence it likewiſe happens, that theſe little bodies muſt be very eaſily moveable any way upon the motion of the maſs, or liquor they compoſe; and that being very ſmall, and moving ſo many ways, they are very unfit to bound themſelves, but very eaſy to be bounded by any other firm body, which hinders them from ſpreading any farther; and yet to continue their various and diffuſive motion as much as they can, they muſt neceſſarily move to and fro, till their progreſs be ſtopp'd by the internal ſurface of the veſſel; which, by terminating their motion, obliges the liquor exactly to accommodate itſelf to whatever figure that ſhall happen to be of.

Experiments to illuſtrate and confirm the doctrine of fluidity.

This general account of fluidity may be farther illuſtrated, and confirm'd by the following inſtances and experiments. Salt-petre may be made fluid either with or without a liquor. And firſt, it puts on the form of a fluid body, by ſolution in water, which entring the pores of the ſalt, disjoins, and divides it into parts ſo ſmall, that it is eaſy for thoſe of the water, wherewith they are aſſociated, to ſupport and move them. But fixed nitre, expoſed to the moiſt air of a cellar, will run *per deliquium*, into a liquor, which conſiſts of no more aqueous particles than are neceſſary to keep the ſaline ones in the agitation requiſite to fluidity. The fluidity it is capable of, without a liquor, may be of two kinds: for, firſt, if it be beaten into an impalpable powder, this, when it is poured out, will reſemble a liquor, though its fluidity be imperfect. But if, with a ſtrong fire, this powder'd nitre be melted, then each of the ſaline corpuſcles, being ſub-divided, and variouſly agitated, the whole body will appear a perfect liquor: and ſuch is the fluidity of melted metals. And not only fire is able to make hard bodies fluid; for ſome may be render'd ſo by others, which to the touch ſeem cold, if they are but fitted to change the texture of the hard body, and put its parts into a convenient motion; as appears in turning camphire into an oil, by letting it lie upon *Aqua fortis*. Camphire may, alſo, by a dextrous application of heat, be brought, in cloſe glaſſes, both to flow, and to boil almoſt like oil. It is true, ſuch liquors taken from the fire, quickly grow ſolid again; but the duration of a thing is not always neceſſary to denominate it: for the leaf of a tree, whilſt it flouriſhes, may be as truly green, as an emerald; though the leaf will, after a while, wither and turn yellow, which the ſtone will not. And, in cold climates, lakes, *&c.* are frozen hard, notwithſtanding the ſame portion of matter was, a little before, a fluid body, and will be thaw'd into a liquor again.

It may be requiſite here to obſerve, that the fluidity, acquired by ſalt-petre upon fuſion by fire, ſeems of kin to that which it acquires by ſolution in water; for both will appear to be cauſed by the pervaſion of a foreign body: only in diſſolution the fluid is a liquor, and conſequently more groſs; whereas, in fuſion, the fluid ſubſtance, that permeates it, is more thin, divides it into much ſmaller parts, and adds very little to its bulk. And it is a notable experiment to this purpoſe, which I have made with

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with finely powder'd alabaſter, or plaiſter of *Paris*; for putting it in a baſon over a fire, it will, when hot, aſſume the appearance of a fluid, by rolling in waves, yielding to the touch, ſteaming, *&c.* all which properties it again loſes on the departure of the heat; and being thrown upon paper, will not at all wet it, but immediately diſcover itſelf to be as moveleſs an incoherent powder, as before it was ſet over the fire: whereby it appears, that a heap of ſuch little bodies, as are neither ſpherical, or otherwiſe regularly ſhaped, nor ſmall enough to be below the diſcernment of the eye, may, without either fuſion, or being poured out, be made fluid, barely by a ſufficiently ſtrong and various agitation of the particles which compoſe it; and, moreover, loſe its fluidity immediately upon the ceſſation thereof*. PHYSICS.

Inteſtine motion requiſite to fluidity.

Hence we ſee how much it conduces to the making of a body fluid, that its ſmall parts be actually moved; but whence this motion proceeds, we ſhall not, at preſent, venture to determine: ſince not writing elements of philoſophy, but concerning fluidity, which is only a ſecondary, or derivative quality, it is ſufficient, that we deduce it not from the unintelligible ſubſtantial forms of the bodies, but from thoſe ſimple and general properties of matter, the figure, ſituation, and motion of its ſmall parts †.

The difference between a fluid body and a wetting liquor.

There is yet one thing more, to be learnt from ſalt-petre, as to the nature of fluidity, and that is the diſtinction between a fluid body, and a wetting liquor; which, becauſe they agree in many things, are uſually confounded: for tho' every wetting liquor be fluid, yet every fluid body does not wet. The air, the æther, and even flame itſelf may, properly, be called fluid bodies; yet will ſcarce by any one be termed moiſt liquors: ſalt-petre, whilſt in fuſion, is really a liquor, and ſo is every melted metal; yet theſe wet not the bodies they touch, like water and other liquors which are fluids, with this peculiar qualification, that they ſtick to and moiſten the dry bodies in contact with them: ſo that the humidity of a body is but a relative thing, and depends chiefly upon the congruity or incongruity of the component particles of the liquor, with regard to the pores of thoſe bodies it touches; as may be exemplified in quick-ſilver, which cannot be ſaid to be a humid body in reſpect of almoſt all other bodies, upon whoſe ſurfaces it will roll, without leaving any of its particles lodged in their pores; but with regard to ſeveral metals, eſpecially gold and tin, it may be called moiſt, for it inſinuates itſelf into their pores, and thereby mollifies their bodies, as other liquors do to other dry ſubſtances. And even water, which wets almoſt all animal and vegetable bodies, ſeems not a humid liquor in reſpect to the feathers of water-fowl. And it is obſervable, that upon the change of tex-

* 'Tis remarkable, that M. *Homberg*, having ſet ſome oil-olive to digeſt, for two months, upon quick-ſilver, the oil, in that time, became ſo thick and hard, that the mercury underneath wanting, as he ſuppoſes, that freedom of motion which is neceſſary to its fluidity, became like a perfect ſolid maſs, tho' of itſelf it was not fixed; but appear'd fluid again, upon being taken out of the veſſel. *Hiſt. de l'Acad.* A. 1708. p. 80.

† We muſt here obſerve, that what Sir *Iſaac Newton* demonſtrates of fluids, ſeems to make againſt the neceſſary exiſtence of any ſuch actual motion in their parts, as is here ſuppoſed. See *Newton. Princip.* p. 260, 261.

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PHYSICS. ture in a liquor, it may be brought to ſtick to the ſurface of a body, on which before it would not faſten; for tho' quickſilver alone will not adhere to glaſs, yet if there be mixed with it a due proportion of lead, tin, and tin-glaſs, tho' neither of theſe will ſtick to glaſs, yet their liquid mixture readily does, even without the aſſiſtance of heat.

Farther proofs of inteſtine motion in fluids. If it be objected, that this various agitation of the inſenſible parts of water, and the like bodies, wherein we make the nature of fluidity chiefly to conſiſt, is but an imaginary thing, and precariouſly aſſerted, ſince the particles themſelves are ſo ſmall, that they, and the diverſity of their motions are imperceptible by ſenſe; it may be replied, that the particles whereof liquors conſiſt, being too ſmall to be viſible, and being not only voluble, but in actual motion, the pores or vacant ſpaces between them, muſt, alſo, be too little to be diſcerned by the eye, and, conſequently, a fluid body muſt appear an uninterrupted or continued one. 'Tis true, a heap of grains of nitre, tho' upon its effuſion out of the veſſel, it ſomewhat reſembles a fluid body, does yet, when it reſts in the veſſel, appear to be but an aggregate of many little incoherent bodies laid together; becauſe the intervals left between them, are great enough to affect the ſenſe: but if the ſame ſalt be reduced into an impalpable powder, the particles and intercepted ſpaces, being then extremely leſſened, the body they make up will much more reſemble an entire maſs, tho' view'd at a leſs diſtance; and ſo when this powder is, by the fire, farther broken into parts incomparably ſmaller than thoſe of the powder, and which, conſequently, intercept extremely little pores, why ſhould we deny that theſe may be little enough, not any where to diſcontinue the body as to ſenſe? And that the inchoherent parts of fluids are alſo variouſly agitated, tho' our ſenſes cannot diſcern it, may be proved by their ſenſible operations. For without ſuch local motion, how could the particles of water penetrate into the receſſes of bodies, and occaſion thoſe putrefactive alterations, uſually imputed to ſuperfluous moiſture? And how comes it elſe to paſs, that aqueous liquors ſo readily mix with one another? And, without this, how could ſugar, or ſalt, caſt into them, be inſtantly ſo perfectly diſſolved and diffuſed every way*? This is evident particularly in ſea-ſalt; which, when the ſuperfluous liquor is ſufficiently exhaled, begins

* This ſolution of ſalts in water Sir *Iſaac Newton* accounts for from another principle. "If," ſays he, "a very ſmall quantity of any "ſalt, or vitriol, be diſſolved in a great quantity "of water, the particles of the ſalt, or vitriol, "will not ſink to the bottom, tho' they be heavier *in ſpecie* than the water; but will evenly "diffuſe themſelves into all the water, ſo as to "make it as ſaline at the top as at the bottom. "And does not this imply, that the parts of "of the ſalt, or vitriol, recede from one another, and endeavour to expand themſelves, "and get as far aſunder as the quantity of water will allow? And does not this endeavour "imply, that they have a repulſive force, "by which they fly from one another, or at "leaſt, that they attract the water more ſtrongly than they do one another? For as all things "aſcend in water, which are leſs attracted "than water, by the gravitating power of the "earth; ſo all the particles of ſalt which float "in water, and are leſs attracted than water, by "any one particle of ſalt, muſt recede from that "particle, and give way to the more attracted water." *Newton. Optic.* p. 362, 363.

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viſibly to coagulate upon the ſurface of the water. And not only ſalt, but even gold itſelf, may have its parts ſo diffuſed by the agitation of theſe liquors; as may be eaſily try'd, by putting a little of the ſolution of gold made in *Aqua regis* into 15 or 20 times as much fair water; which will all, thereby, be immediately ennobled with a golden colour. That the little bodies whereof flame conſiſts, are fiercely agitated, often appears even to the eye, and will ſcarcely be denied by him, who conſiders its operations. And that the particles which compoſe our common air, are alſo variouſly agitated, we are induced to believe, by ſeveral particulars; as, by thoſe little motes we ſee floating up and down in the ſun-beams; by the tremulous motion, which that of ſwarms of little bodies in the air, ſeems to impart to diſtant objects, view'd after ſun-riſe through a good teleſcope; and by the fuſion of ſalt of tartar in the air; which would not happen, if the moiſt vapours, that help to conſtitute it, did not move about therein; and were not thereby brought to the ſalt, and enabled to inſinuate themſelves into its pores, and, by that means, diſſolve, and reduce it, with themſelves, into a liquor. And, even in ſummer, when the air is drier, than at other ſeaſons, we may diſcover plenty of aqueous corpuſcles floating in it; from their gathering in drops upon glaſs, and ſuch hard bodies, wherein any cold thing is contain'd. Whence uſeful hints may be taken, of catching a ſalt and liquor out of air, barely by glaſs veſſels of a peculiar and ſkilful contrivance. And experience has taught us, that it is not difficult, by a convenient furnace, to make even lead aſcend to a very great height in the open air, in the form of ſmoak. And tho' quick-ſilver be, excepting gold, the heavieſt known body in the world; yet, when it is reduced into vapour, it ſeems to be carried to and fro, like other particles, which ſwim in our air: for an expert gilder complained to me, that its fumes would often lay hold of his gold rings, and change them white.

But let us return to viſible liquors, and ſee whether their inſenſible parts may not be every way agitated, tho' their motion be ſeldom viſible. Diſſolve any quantity of ordinary coin'd ſilver in *Aqua fortis*, pour the ſolution into twelve or fifteen times as much fair water; and then decant, or filtre the mixture, that it may be very clear. If you look upon this liquor, the parts of it will ſeem to be, all of them, as perfectly at reſt, as thoſe of common water: nor will your eye be able to diſtinguiſh any corpuſcles of ſilver ſwimming in the liquor; yet, that there are ſuch metalline corpuſcles agitated to and fro, with and by thoſe of the water, will quickly appear, if you immerſe into it a flat piece of clean copper; for you ſhall ſee the particles of ſilver faſten themſelves in ſwarms to the copper-plate, and cover it with a looſe caſe of ſilver, eaſily to be ſhaken off in the form of a metalline powder: and if ſeveral ſuch plates be left all night in the bottom of the veſſel, you may, the next day, find all the particles of ſilver, that were diſperſed through the whole body of the liquor, ſettled upon them; a deep bluiſh green tincture appearing in the water, and proceeding only from ſome little parts of the copper diſſolved by the menſtruum. And, to compleat the experiment, I have made even theſe fall to the bottom of the veſ-

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PHYSICS. ſel, by leaving a lump or two of ſpelter there for two or three days: for not only thoſe metalline corpuſcles, that were juſt over, or near to the determinate place, where I put the ſpelter; but all the reſt, into how remote parts ſoever of the liquor diffuſed, ſettled upon it; as appear'd both by its increaſe of bulk, and by their leaving the water clear and colourleſs: which plainly ſeems to have proceeded from hence, that the particles of the water were reſtleſsly, and every way agitated; and ſo, by frequently gliding along the ſurface of the ſpelter, carry'd thither the corpuſcles of the copper mixed with them, ſome at one time, and ſome at another, till, at length, all were brought to it, and detained there.

But farther, to try this agitation in ſpirit of wine; I let fall into a wide-mouthed glaſs, fill'd with that liquor, a little common oil of turpentine; and the drops ſwimming at the top, continued to move to and fro, in an irregular pleaſing manner, for above half an hour; till the ſpirituous parts being flown away, they reſted upon the remaining fluid, as they would upon common water. I repeated the experiment, with the ſame ſucceſs, in another inflammable liquor; and found, not only that the oil, but ſome ſmall ſtraws alſo, gently let fall upon the ſurface of the ſpirit, were tumultuouſly carried about thereon. And this agitation of the minute parts, not only holds in light and ſpirituous liquors; but that the inſenſible parts, even of the heavieſt fluids, are alſo in actual motion, will follow from what has been deliver'd of the nature of fluid bodies: and may be confirmed by this; that as three of the heavieſt liquors, we yet know, are quick-ſilver, oil of tartar *per deliquium*, and oil of vitriol; the firſt will, even in the cold, enter the pores of gold, and deſtroy its texture; the liquor, alſo, of ſalt of tartar, will, in the cold, draw tinctures from ſeveral bodies; and the agitation in oil of vitriol appears, from its corroding metals, and diſſolving camphire without heat. Whoever yet doubts, whether the parts of theſe two oils, as they are called, are fiercely agitated, may, probably, be ſoon ſatisfied, by ſhaking a little of them together, and obſerving the heat, hiſſing, ebullition, and ſparkling that will ſuddenly enſue.

But though it be eſſential to fluids, that their parts eaſily ſhift places; yet this is to be underſtood, only as to the parts of the ſame fluid, as water; or of ſuch different ones, as are diſpoſed to admit each other's particles, and unite together as water and wine: otherwiſe, they may be of ſuch different natures, that, when two or more of them are put together, they will not mix, but each retain its own diſtinct ſurface; as is obvious in oil, which mixes not with water; and quick-ſilver will not incorporate with any of the common liquors.

Why different contiguous fluids preſerve their ſurface diſtinct.

As to the cauſe why theſe liquors retain diſtinct ſurfaces, I ſhall here only obſerve, in general, that it ſeems to depend very much upon the texture of them, and, perhaps too, upon the peculiar motions of their minute parts. For though pure ſpirit of wine, and ſalt of tartar reſolved into a liquor by the air, will, when put together, retain diſtinct ſurfaces, or preſently regain them, tho' you ſhake the liquors ever ſo ſtrongly together; yet, by adding a little fair water to either of them, the texture being

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ing thereby altered, it will eaſily incorporate with the other. And thus, PHYSICS. tho' common ſpirit of turpentine will not mix with ſpirit of wine; yet, if ſkilfully drawn, with a very gentle fire, they may, by ſhaking, be united. And again, tho' lixiviate ſalts and oils will not join; yet, by digeſting, for ſome time, a ſolution of ſalt of tartar with oil of almonds, I could reduce them to a ſoft ſoapy ſubſtance.

A farther difference obſervable in contiguous fluids, is, that ſome of them not only refuſe to unite with others, but faſhion their ſurfaces to determinate ſhapes; for having pour'd ſpirit of wine upon oil of tartar *per deliquium*, I found that the ſuperficies, wherein they touched, was flat, or parallel to the horizon: but if this were done in a very narrow glaſs, with the mouth open, tho' the lower ſurface of the ſpirit of wine, which touched the other liquor, appear'd very level; yet the upper ſuperficies, contiguous to the air, was very manifeſtly concave. And if to theſe two liquors, in a broader glaſs, oil of almonds were poured, it would ſink to the bottom of the ſpirit of wine; and, floating upon the oil of tartar, ſeparate the two liquors, and, both above and below, retain a flat or level ſurface. But if, inſtead of oil of almonds, I dropped into pure ſpirit of wine, ſwimming upon oil of tartar, ſome common oil of turpentine, this oil would gather into parcels; which, in caſe they ſwam in the ſpirit of wine, and touched neither of its ſurfaces, ſeemed globular; and continued ſo (the glaſſes being ſtopped) for many hours: but if they emerged to the upper part of the ſpirit of wine, as much of them as lay immerſed in the ſpirit, appeared round; and continued ſo as long as I pleaſed; the upper parts only of thoſe little globes appearing to have the ſame ſurface with the ſpirit. I farther obſerved, that ſome ſmall drops would conſtantly reſt upon the ſuperficies of the oil of tartar, touching it but in a point, and continuing to the eye ſpherical; tho' the ſurface of the liquor were, now and then, purpoſely ſhaken. But I more particularly obſerv'd, that having, into pure ſpirit of wine, let fall ſome large drops of oil of turpentine; they, at firſt, ſunk to the bottom of it, and lay upon the ſurface of the oil of tartar, almoſt like hemiſpheres, whoſe convex part was all above the oil of tartar: but, after a while, they were preſs'd on all ſides, and faſhion'd into round bodies. I took equal quantities of common oil of vitriol, and common oil of turpentine; and, very gradually putting them together, obtained an opake, and very deep-colour'd mixture, whoſe conſiſtence was much thicker than either of the liquors which compoſed it. And to ſhew, that the diſpoſition of theſe liquors, to unite thus ſoon together, depended much upon their texture; we warily diſtilled the mixture, and obtained a certain groſs ſubſtance, which ſeemed to mediate the former union betwixt them: for this ſubſtance being ſeparated, and thereby the texture of one of the fluids, or perhaps both, being changed, the liquors, which came over very clear into the receiver, ſwam upon one another: nor have I ſince been able, by ſhaking them together, to confound them, for any conſiderable time; but they preſently part again, and, to this day, remain both diſtinct, and tranſparent. Now, drops of water, quick-ſilver, and other fluids, ſeeming to be faſhioned into

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PHYSICS. a round figure, by the equal preſſure of the ambient air; I thought proper to intimate, how ſome experiments might be made to account for the figuration of the more conſiderable fluids, which make up much the greater part of the univerſe; eſpecially, ſince, 'tis probable, that ſuch ſteams of the terreſtrial globe, as may well be ſuppoſed the chief ingredients of our atmoſphere, may, like a liquor, retain a ſuperficies diſtinct from that of the ſurrounding and contiguous body.

Diſſolve one ounce of clean common quick-ſilver in two of pure *Aqua fortis*, ſo that the ſolution may be clear and total; whilſt 'tis yet warm, pour in, by degrees, half an ounce, or an ounce of lead filings; and if no error has been committed, or unlucky accident intervened, the lead will immediately be precipitated into a white powder, and the mercury reduced to a maſs of running quick-ſilver, over which will ſwim the remaining part of the *Aqua fortis*. Whence we ſee, that liquors, being reduced to very minute parts, may unite; the corpuſcles of the one ſupporting thoſe of the other; whilſt, the texture of the one being varied, they retain diſtinct ſurfaces.

Before we quit this ſubject, it muſt be farther obſerved, that, not only in fluid bodies, but in ſome alſo of thoſe which are conſiſtent, there may, perhaps, be more motion, than our ſenſes diſcern. A cluſter of ſwarming bees, view'd at a diſtance, ſeems to be one intire body; yet each particular bee has its diſtinct and peculiar motions: but theſe motions of them all deſtroy not the coherence of the cluſter; becauſe, when one of the innermoſt bees removes, as ſhe lets go her hold from thoſe whereon ſhe reſted before, and quits thoſe which reſted upon her, ſo ſhe meets with others, on which to faſten; and comes under others, which, in like manner, ſet their feet on her: ſo that, by this change of mutual ſupports, their coherence, and removes, are made conſiſtent: and if, inſtead of bees, the ſwarm conſiſted of extremely minute flies, their particular motions would, perhaps, be inconſpicuous. And that ſome ſuch thing may happen in conſiſtent bodies, ſeems probable; becauſe, in wainſcot, and other hard wood, we often ſee little heaps of duſt, produced by putrefaction: and not only in cheeſe, but in apples, and other fruits, we often find maggots, tho' the rind be whole; which could not happen, unleſs the parts of the matter were variouſly tranſpoſed, and connected after a manner ſuitable to the nature of the inſect to be produced. And, by the growth of bones in the bodies of perfecter animals, as alſo by the growth of the ſhells of oyſters, and ſnails, from a ſize inconſiderable at firſt, in regard of what they afterwards attain to; and by ſome other reſembling particulars, it ſeems that the ſmall particles, which conſtitute even the ſolid parts of animals, are not, whilſt the creature lives, exempt from ſome local motion. It hath been affirmed to me, by a very diligent obſerver, that he ſaw ſeveral pieces of gum ſweat out of an old wainſcot, that had ſtood above twenty years: and I have, ſeveral times, ſeen viſcous exſudations, like drops of turpentine, upon deal-boards, which had been uſed in buildings.

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We might now diſcourſe of the advance, or hinderance, in reſpect of fluidity, that one body may receive, by being mixed with another; but we ſhall, at preſent, only obſerve, that it is not ſo ſafe, to foretel the conſiſtence of a mixture of two or more bodies, from the bare conſideration of the conſiſtence of thoſe whereof it is to be compounded. And to examine what many chymiſts, without limitation, teach, as to the addition of ſalts, to metalline and mineral bodies, to facilitate their fuſion, I diſſolved crude copper in ſpirit of nitre; and, by evaporation, reduced the ſolution to a vitriol. We alſo corroded, with two parts of ſpirit of nitre, one of good tin, and ſuffered the mixture to reduce itſelf to a ſubſtance, almoſt like meal; of this mixture, we put a parcel into a crucible, and made it red-hot: we alſo expoſed ſome of it to a ſtrong naked fire, without finding it fuſe at all; tho' ſalt-petre be a fuſible ſalt, and tin very eaſy to melt. And tho' copper be of much harder fuſion, not only than tin, but even than ſilver; yet, being joined, *per minima*, with the ſame kind of nitrous corpuſcles, that had ſuch a contrary effect upon tin, ſo ſtrangely diſpoſed it to fuſion, that the vitriol would melt with the heat of one's hand. Nay, we have made ſuch a vitriol, either with ſpirit of wine, or *Aqua fortis*, as would, even in winter, ſtand melted for ſeveral hours together, by the heat of the ſun ſhining on it thro' a window. So fit it is, that we conſider, as well the new texture, which mixed bodies obtain by the aſſociation of their particles, as the conſiſtence of the particular bodies, before they are mixed.

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The conſiſtence of bodies upon mixture, hard to determine à priori.

SECT. II.

THE chymiſts aſcribe the firmneſs of bodies to ſalt; and tell us that is the principle of coagulation, and the cauſe of ſolidity. But tho' this opinion be ſo generally receiv'd, that it may ſeem ſuperfluous to enquire after other cauſes of theſe qualities; yet we ſhall venture to conſider the matter. And, having already taken a general view of fluidity, let us try what light it will afford us, to diſcover the nature of firmneſs. Now, ſince fluidity, and ſtability, are contrary qualities, they muſt be apprehended under contrary notions; we may, therefore, conceive, that the firmneſs, or ſtability of a body, conſiſts principally in this; that the particles which compoſe it, being ſomewhat groſs, are alſo at reſt, and have a mutual coheſion, whereby they are rendered unapt to diffuſe themſelves every way: ſo that its three principal cauſes appear to be groſſneſs, quiet contact, and an implication of the component parts.

Firmneſs, what?

As to the firſt, larger corpuſcles being, *cæteris paribus*, harder to be put into motion than leſs, when they are once at reſt; it is obvious, that a body, conſiſting of ſuch particles, is leſs diſpoſed to become fluid, and conſequently more apt to continue firm, than if its component parts were ſmaller, and thereby more eaſy to be diſplaced. By groſs corpuſcles, I underſtand ſuch as are ſcarce diviſible into leſs, by the agitation of the ambient air, or any other cauſes of fluidity. And in ſpeaking of the fitneſs of groſſer cor-

The requiſites to firmneſs; viz. groſſneſs of parts.

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PHYSICS. corpuſcles to make a firm body, I add *cæteris paribus*, becauſe 'tis poſſible, that the breaking of the ſmall parts of a body into minute particles, may the more fit them to contribute to the firmneſs of the body whereto they belong. For the parts of the divided corpuſcles may, by their comminution, acquire a new, and perhaps a more irregular ſhape than before; upon which account, they might be more diſpoſed to be entangled among the neighbouring particles, or be better fitted to get into, and fill the pores of ſome kind of bodies. And, in ſuch little particles, not only the minuteneſs may make them lie cloſer together, and conſequently the better exclude the air; but the greatneſs of the ſurface, in proportion to the bulk of the matter, may perhaps, in ſome caſes, occaſion a fuller contact, and ſo facilitate the conſtitution of a very firm body, in caſe theſe minute parts ſhall be diſpoſed to the beſt advantage for a full contact with one another. But, from what was delivered of the ſize of parts, in treating of fluidity, it may eaſily be underſtood, how much the magnitude of them will conduce to firmneſs. We now paſs on to the two other requiſites of conſiſtent bodies, the one whereof is the bare reſt of the parts which compoſe the firm body; and the other, the intricate texture of ſuch parts. And either of theſe ſeems, alone, ſufficient to render a body ſtable; tho' nature, perhaps, often makes uſe of both, to faſten the parts of the ſame body more firmly together.

Reſt and cohesion. If two bodies be once at reſt in contact, they muſt continue in that ſtate, till ſome force, able to over-power their reſiſtance, diſturbs them. And, whatever is ſaid of the conſtant mobility of atoms, yet, that ſeveral parts of matter may compoſe bodies, which need only juxta-poſition to unite them, whereby the air, or other fluids that might diſſociate them, are excluded, I am inclined to think, by what I have obſerved in grinding of glaſſes: for here ſometimes the convex ſurface of one body being ground upon the concave ſurface of another, the two ſurfaces will be ſo cloſely fitted to one another, that a man is not able, without breaking one, or both, to pull them directly aſunder; but if you will ſever them, you muſt be obliged to make one ſlip along the ſurface of the other: which makes the glaſs-grinders often complain of the trouble they meet with in ſeparating ſuch bodies. Nay, if you lay two flat glaſſes, ground very true, and well poliſhed, upon one another, ſo that their ſurfaces may almoſt every where touch, you may by lifting up the upper, raiſe the lower with it, as if the two plates of glaſs made but one body. And I have often taken up four or five pieces of glaſs at once, thus laid and preſs'd one upon another; and might, perhaps, have taken up a greater number. Experience alſo aſſures us, that if a looking-glaſs be held very level, with the unfoliated ſide downwards, and you rub a piece of other very flat ſmooth glaſs a little againſt it; you may eaſily by that way only, faſten them to one another, ſo that the lower, tho' large, will be ſtrangely ſuſpended between the uppermoſt and the ground. And, by the ſame way, we have made one conſiderably thick piece of marble take up another, having firſt cauſed their flat ſurfaces to be carefully ground. Nor is it requiſite, that the glaſſes be flat, to make them adhere very cloſely together, pro-

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provided their immediate contact be made in a large ſurface: for, having, purpoſely, applied a long glaſs-ſtopple, of an almoſt conical figure, and well ground, to the mouth of a thick quart-bottle, whoſe neck was long, of a figure convenient to receive the ſtopple, and ground within fit for it; we found, that theſe two glaſs-bodies, touching one another in a multitude of parts, adhered together ſo cloſely, that, when the ſtopple was carefully put in, we could eaſily lift up the bottle by it, with above a pound of liquor in it*. Yet here we muſt obſerve, that the ſticking together of ſuch bodies as are of a ſenſible bulk, and whoſe ſmooth ſurfaces immediately touch one another, may, poſſibly, not proceed ſo much from their parts being at reſt among themſelves; and, by their immediate contact, making up, as it were, one body; as from the preſſure of the atmoſphere, proceeding from the weight of the ambient air, and from a kind of ſpring, by virtue of which, the air continually preſſes upon the bodies contiguous to it; though, thro' negligence, and, perhaps, ſome other cauſes, we neither feel it in our own bodies, nor take notice of it in others. Now this preſſure of the air every way, being ſuppoſed, I think the mutual adheſion of the ſmooth bodies we ſpeak of, may, probably, be aſcribed to this; that when the ſmooth ſurfaces of two pieces of glaſs, ſo exquiſitely touch one another, that none of the ambient air, is either intercepted, or admitted between them, the under glaſs will ſuffer no preſſure on that ſide, which touches the upper, the parts of the upper glaſs having no ſenſible ſpring in them; whilſt that ſide of the under one, which is expoſed to the air, will be preſſed upon thereby: and there being, as we ſaid, no elaſtical preſſure on the other ſide of the glaſs to ballance this, no wonder that the lower glaſs ſhould not fall off from the other, ſince the weight that would carry it downwards, is much too ſmall to overcome that force of the air, which thruſts it againſt the upper glaſs. Thus if a man ſhould, with his hand, thruſt a plate of iron, broad-wiſe, againſt the flat ceiling of a chamber; the iron would not fall, as long as the force of the hand continues to preſs againſt it. Nor is it material, that, in our caſe, the preſſure of the atmoſphere is ſuppoſed to force the lower glaſs upwards: for if we ſuppoſe the air to conſiſt of innumerable little ſprings, bearing upon, and ſupporting one another, the lower whereof are bent by the weight of all the reſt, incumbent on them; it will be eaſy to conceive, that, near the ſurface of the earth, it may preſs almoſt equal every way; and by a kind of recoil, from the terreſtrial globe upwards, ſtrongly force any body, upon which it can bear, againſt any other, which has no ſuch elaſtic power to repel a body ſo preſſed againſt it.

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The preſſure of the atmoſphere one cauſe of coheſion in bodies.

We ſhall now proceed to confirm our conjecture as to the reaſon why ſmooth bodies ſtick together, barely by juxta-poſition, or contact. And, firſt, tho' a piece of flat glaſs may be ſuſpended by a looking-glaſs, held parallel to the ho-

* This ſtrong coheſion of the parts of matter, is by Sir *Iſaac Newton* attributed to a principle of attraction, which, in immediate contact, is exceeding ſtrong, but reaches not far from the particles with any ſenſible effect. See *Newton. Optic.* p. 351—372.

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PHYSICS. rizon; yet, if, by inclining the looking-glaſs, it loſeth that level, the ſmaller glaſs will ſlide downwards upon the ſurface of the greater. The reaſon whereof ſeems to be, that the gravity of the lower glaſs does not conſiderably reſiſt the horizontal motion of it, only the motion upwards; but chiefly, becauſe the ambient air is contiguous to the edges of the glaſs, as well on the one ſide, as on the other: and ſo the preſſure of the air being equal on every part of the edges, the gravity of the ſmaller glaſs is not hindered, by the air, from ſliding down the ſhelving ſurface of the greater: whereas, of the broad and flat ſides of the lower glaſs, the one is, as we ſaid, preſſed by the ſpring of the air; whilſt the other ſuffers no ſuch preſſure from the looking-glaſs, to which it was applied. And ſo, if you take a ſmall open-mouthed glaſs, and plunge it into a veſſel full of quick-ſilver, with the mouth upward, that the quick-ſilver may fill it, without leaving any air in it; and if then, whilſt it is under the quick-ſilver, you turn the mouth downwards, and ſo, keeping it upright, lift it up, till the mouth be almoſt come to the top of the mercury; the glaſs will remain almoſt full of quick-ſilver, tho' the upper ſurface of the liquid metal in the glaſs be much higher, than the level of the ſurface of the quick-ſilver in the veſſel: and this will continue ſo, tho' you incline the glaſs, provided you keep the mouth of it within the mercury. The experiment will alſo ſucceed, when made with water. The reaſon hereof ſeems to be, that the glaſs hinders the quick-ſilver in it from the preſſure of the incumbent air; whereas, the quick-ſilver in the veſſel being expoſed to it, muſt, thereby, be neceſſarily forced up againſt the ſurface of the inverted bottom of the glaſs, where it meets no elaſtic power to drive it downwards: for that it is not nature's abhorrence of a vacuum, which keeps the quick-ſilver from deſcending, till ſome air can come to ſucceed in its room, ſeems clear from the *Torricellian* experiment. And to ſhew, that it is not ſo much the mere contact of bodies in a large ſurface, as its being ordinarily requiſite to the excluſion of air, which, at leaſt here below, keeps bodies from falling aſunder; having, out of a large glaſs, cauſed a certain quantity of air to be extracted, we found, that, by immediately applying a book to the narrow orifice of the veſſel, the book was afterwards readily lifted up, and ſuſtained in the air, as long as we pleaſed; tho' the ſurface of the ſuſpended body could be touched but by the ring, which incircled the orifice of the veſſel; and tho' the weight taken up exceeded twenty ounces. The cauſe whereof ſeems plainly this; that, by the exſuction of ſome air out of the glaſs, the elaſtic power of the remaining part was much weaken'd, in compariſon of the ſpring of the external air; which being able to preſs the book againſt the orifice of the veſſel with greater force, than the internal air could reſiſt, the mouth and lips of the veſſel, on this occaſion, perform'd the part of an intire ſurface, exactly ſmooth. And, by the way, upon this principle may, poſſibly, depend the ſolidity of glaſs: for though its parts ſeem not at all interwoven, and appear very ſmooth and ſlippery; yet, ſince the fire, which brought them to fuſion, may well be ſuppoſed to have ſub-divided them into very ſmall particles, and to have thereby aſſiſted to exclude the air

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air from between them, 'tis no wonder, if the immediate contact of ſuch ſmall corpuſcles ſuffices to make them hold together; for that their union is ſtrict enough to keep out the air, appears, ſince the glaſs-blowers, and thoſe who diſtil in glaſſes, find not that it can enter their pores. 'Twere alſo proper to conſider, how much the juxta-poſition of corpuſcles, crowded together by fuſion, may contribute to the conſiſtence and brittleneſs of ſalt-peare, and other bodies, which, from an incoherent powder, are readily reducible into one maſs: as, likewiſe, how far the ſticking together of the ſmall parts of pendulous drops of water, and ſuch other liquors as are not thought to conſiſt of corpuſcles hooked, or branched, may be aſcribed to the contact of their ſmall parts, and the excluſion of the air. But to return: tho' it be hence manifeſt, that the air hath a ſtrong ſpring; yet, there appears no great neceſſity for it to ſhew why the two ſmooth glaſſes were able to adhere ſo cloſely. For a probable reaſon of that phenomenon may be aſſign'd from the preſſure of the air, conſidered as a weight. And, firſt, we muſt remember that a cylinder of air, which is not without its gravity, recoiling from the earth, to the ſuſpended piece of glaſs, being hindred by the reſiſting ſurface of the terreſtrial globe from falling lower, muſt diffuſe itſelf, and, conſequently, preſs as well upwards, as any other way. Next, we muſt conſider, that when the ſurfaces of two flat bodies, of any conſiderable breadth, immediately touch each other, and lie, both of them, level with the horizon; ſince the air cannot move, in an inſtant, from the edges to the middle, the lower cannot be drawn away downwards, in a perpendicular line from the upper; but, by reaſon of the ſtiffneſs, and contact of the two bodies, it muſt neceſſarily happen, that, at the inſtant of their ſeparation, ſhould it be effected, the loweſt glaſs will be preſſed upon by the whole pillar of air, ſuppoſed to reach from the top of the atmoſphere, and to have for its baſis, the ſuperficies of the under glaſs. For, at that inſtant, the air having not time to get in between the two glaſſes, there is nothing between them, during that inſtant, to reſiſt the preſſure of that air, which bears againſt the lower ſuperficies of the undermoſt; and, conſequently, ſuch a revulſion of the lower glaſs cannot be effected, but by a weight, or force, able to ſurmount the power of the weight of the above-mentioned cylinder of the atmoſphere. Hence, we ſee it is not neceſſary, that the contiguous ſurfaces of the two flat glaſſes be parallel to the horizon; for, if held perpendicular to it, their divulſion would not ceaſe to be difficult, provided it were attempted by ſuddenly pulling one of the broad ſurfaces from the other, in a level line, and not by making one of the ſurfaces ſlide upon the other: for, in the former caſe, the ſeparation of the contiguous bodies will be hindred, by the weight, or preſſure of the lateral air, which bears againſt the broad ſides of the glaſſes contiguous to it. But as in theſe caſes, we ſuppoſe the ſuperficies of the two glaſſes to be ſo exactly flat, that no air can come between them; experience has inform'd us, that it is extremely difficult to procure, from our ordinary tradeſmen, either glaſſes, or marbles ground near ſo true. We very hardly obtain'd a pair of round

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PHYSICS. marbles, of an inch or two in diameter, which would, for two or three minutes, hold up one another in the air by contact; tho' they would eaſily raiſe each other, if the uppermoſt was drawn up nimbly, before the air had time to inſinuate itſelf betwixt them.

But to make ſome eſtimate of this power in the air; having provided a pair of marbles, an inch and half in diameter, and as flat and ſmooth as poſſible; and conſidering, that it was the inſinuation of the air between them, which hindered them from ſticking ſtrongly together; ſo the acceſs afforded to it, was, for the moſt part, owing to that inequality of their ſurfaces, tho' poliſhed; we ſuppoſed that the intruſion of the air might, for ſome time, be prevented, by wetting the ſurfaces to be joined, with pure ſpirit of wine; whilſt this liquor, which ſeems the freeſt from tenacity, would not prove a cement to faſten the ſtones together, otherwiſe, than by keeping out the air. But becauſe the eaſy ſeparation of ſuch ſmooth bodies, which adhere but by contact, may proceed from the leaſt angular inclination; we try'd, in the firſt place, to faſten to the upper marble certain wires, and a button, ſo that the lower, when joined, might freely fall directly down, but not ſlip aſide, being hindered by the wire. And thus the dry marbles were made to take up, and ſuſtain one another; ſo that once, by ſuddenly drawing up the upper marble, we took up, together with the lower marble, a ſcale with a pound weight in it. After this, we moiſtened the ſurfaces of the marbles with pure ſpirit of wine; and keeping them, by our wires, from ſlipping aſide, we caſt into a ſcale, faſtened to the lower of them, ſeveral weights, at ſeveral times; and, by ſuddenly pulling up the higher ſtone, often try'd how much we could draw up with the lower; and ſometimes took up above an hundred ounces, and once one hundred thirty-two ounces troy, beſides the ſcale that contained them, and the marble itſelf; the diameter of whoſe ſurface was only an inch and two thirds. But, becauſe the ſpirit of wine proved too fugitive and ſubtile for our purpoſe, we moiſten'd the ſurfaces with a due proportion of oil of ſweet almonds; and thus we took up above four hundred ounces troy, hanging at the lower marble. It was not by glewing the marbles together, that the oil enabled them to make ſo much greater reſiſtance, than the ſpirit of wine; for in caſe the flat ſurfaces of the joined ſtones were held perpendicular to the horizon, ſo that the air might immediately ſucceed, as the looſer marble ſhould ſlide off, the weight of ſeveral ounces was, ſometimes, requiſite to draw them down, when they had nothing but ſpirit of wine between them; tho' they would eaſily ſlide off from one another, when join'd together with oil; perhaps, becauſe the ſpirit of wine, by reaſon of the ſmallneſs and penetrancy of its parts, and fugitive nature, did not ſo well fill up the little pores of the ſurfaces; whereby the ſmall protuberances of the one, getting into the ſmall cavities of the other, might more reſiſt the ſliding of the marbles upon one another's ſurfaces, than the oil, whoſe texture is better fitted to render their ſurfaces ſmooth and ſlippery.

And

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And to ſhew, that the reſiſtance of ſuch contiguous marbles, to ſeparation, is greater in thoſe which, being broader, are preſſed againſt by a column of the atmoſphere proportionably larger; we cauſed two marbles to be made, three inches in diameter: and having, after the manner abovemention'd, employ'd ſpirit of wine, to keep out the air from between them, we, after ſome tryals, with the uppermoſt of them took up the lower, and four hundred and ſeventy ounces. But making uſe of oil of almonds, inſtead of ſpirit of wine, we did, with our own hands, twice ſucceſſively raiſe, with the undermoſt ſtone, thirteen hundred and forty-four ounces troy; and, at the ſame time, manifeſtly perceived the marble, at which it hung, to ſtick firmly to the other: yet the interpoſed oil was ſo far from being able, as a cement, to make theſe marbles adhere thus cloſe together, that, in this laſt experiment, I made them very freely ſlide upon one another, by impelling the upper to the right hand, or left, with my finger; and, having ſome time before, raiſed a weight not much inferior to the laſt, we, preſently, held the marbles with their edges downwards, and found, that, tho' in an horizontal poſition, they could not be ſeparated by ſo great an additional weight, they now preſently fell aſunder by their own.

I know that the *Peripatetics*, and generality of ſchool-philoſophers, will aſcribe this adheſion of marbles to nature's abhorrence, and dread of a vacuum. But if nature did ſo violently oppoſe a vacuum, it is not likely, that any force we could employ, would be able to produce one; yet, in our caſe, we find, that a little more weight added to the lower of the two marbles, will ſurmount their reluctance to ſeparation, notwithſtanding the ſuppoſed danger of introducing a vacuum thereby. But, without having recourſe to any ſuch diſputable principle, a fair account may be given of the phenomenon, by the preſſure, or weight of the air. Let us ſuppoſe, that when the marbles ſtick firmly together, the lower of them were faſtened to the ground; tho' here there appears no reaſon, why their power to reſiſt ſeparation, ſhould be leſs then before, yet, it ſeems evident, that the uppermoſt marble could not be perpendicularly lifted up, but by a force, that was, at leaſt, able to raiſe a weight equal to that of this marble; and of a pillar of air, having the ſtone for its baſe, and reaching to the top of the atmoſphere: ſince, at the inſtant of revulſion, before the air can get in between, there is, for ought appears, no body under the upper marble, to help the hand to ſuſtain the weight of that, and the incumbent cylinder of the atmoſphere, which then gravitates upon it, and, conſequently, upon the hand; becauſe there is no air, or other equivalent body underneath, to ſuſtain its part of the weight, as the lower air does, with regard to the heavy bodies, which reſt on it, and to the weight of the incumbent air. We need not therefore wonder, if when only a leſs weight than that of the mentioned column of the atmoſphere hangs at the lower marble, it ſhould be capable of being drawn up by the upper, rather than ſuffer a divulſion from it. Thus when two bodies, being faſtened together, are endeavoured to be drawn aſunder by forces not able to ſeparate them, they will uſually both

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PHYSICS. both move that way, towards which either of them is the moſt ſtrongly drawn. And I have ſometimes obſerved, in trying the ſtrength of load-ſtones, if the load-ſtone be able to take up more than its own weight, you may as well lift up the load-ſtone by a knife, as a knife by the load-ſtone. And tho' one accuſtom'd to judge only by his eyes, would have imagin'd, that when I held the great weights, formerly mention'd, ſuſpended in the air, there was no ſtrong endeavour to pull the upper marble from the lower, becauſe my hand, being for a time held ſteady, ſeemed to be at reſt; yet he will eaſily find a great miſtake therein, who ſhall conſider, that neither did the weight ſenſibly appear to pull the lower marble downwards, tho' my hand aſſured me, that the weight had not loſt its gravitation. And once, when the weight was caſually ſo looſened from the upper marble, as ſuddenly to drop down, my hand, unawares, was, by the endeavour it employ'd to ſuſtain the fallen weight, carried up with ſuch a violence, that I bruiſed it againſt the face of a by-ſtander, who chanced to hold his head over the marbles.

A braſs-valve, an inch in diameter, being cemented to the ſhorter leg of a long glaſs ſiphon, left open at the end of the other; this valve was let down to the bottom of a long glaſs body, full of water; till it was between a foot and half a yard beneath the ſurface of the water, when the water in the pipe, reach'd as high as that ſurface. Then, an ounce-weight was put into the ſcale of a balance, oppoſite to that whereto one end of a ſtring was faſtned; its other being connected with the valve, whoſe parts were thereby to be drawn aſunder. Now when the water was emptied out of the pipe, and the valve let down to the former depth, four ounces of additional weight were requiſite to disjoin the parts of the valve, and let the water get between. And when the valve, the ſiphon being freed from water, was raiſed gradually higher together with the pipe, leſs and leſs weight was required to make the ſeparation; an additional half ounce proving ſufficient to disjoin the parts of the valve, when held but a little below the ſurface of the water. From this experiment, attentively conſider'd, it appears, that there certainly may be a great repugnancy, barely on account of the gravity of the medium, to the ſeparation of ſmooth bodies, join'd by immediate contact. But farther, having at length ſuſpended two coherent marbles, in a large glaſs, whence, by a certain contrivance, the air might be gradually exhauſted; we found, whilſt any conſiderable quantity of air remain'd in the glaſs, the lower marble continued to ſtick to the other; but if the air was farther withdrawn, the lower fell from the upper: when, if the latter were let down upon the former, whilſt the glaſs remain'd exhauſted, the upper marble might eaſily be raiſed without taking up the lower; yet when the air was let in, the marbles were again ſtrongly preſſed together, and made to cohere.

From the whole, it appears, that tho' in bodies of a ſenſible bulk, whoſe ſmooth ſurfaces touch one another, the force of the air is the principal cauſe of coheſion; yet, it ſeems, in general, a ſufficient cauſe thereof, that the parts of the body be at reſt by one another; though, perhaps, the entire

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tire cohærction be removed from place to place. For bodies of ſenſible bulk, being either fluid or conſiſtent; and it being the chief requiſite of a fluid body, that its ſmall parts be in motion, nothing ſeems neceſſary to keep a body from being fluid, and conſequently to keep it firm, but that its contiguous parts be in a ſtate of reſt. PHYSICS.

Texture another requiſite to firmneſs.

Another requiſite to firmneſs, is the texture of the parts that conſtitute a body; for, tho' the juxta-poſition, and reſt of theſe parts, may, poſſibly, alone ſuffice to make the body ſtable; yet texture ſeems to be the moſt uſual cauſe of ſtability; and ſometimes alſo, it may ſuperadd a degree of that quality to what bodies have upon the former account only. For tho', while the parts of the body are actually at reſt, it cannot be fluid; yet theſe parts, if they cohere to one another but by reſt only, may, *cæteris paribus*, be much more eaſily diſſociated, and put into motion by any external body, actually moved, than they could if they were, by hooks, or other kinds of faſtenings, entangled with one another; it being often neceſſary, in this caſe, violently to break off theſe faſtenings, before the little bodies, join'd together by them, can be ſet free, and put into ſuch a ſeparate motion, as is requiſite to conſtitute a fluid body. We formerly illuſtrated the nature of fluidity in the white of an egg; let us now try, whether it will alſo aſſiſt us in our ſearch after the cauſes of ſtability. When an egg is made hard by boiling, ſince nothing appears to get in at the ſhell, unleſs ſome calorific atoms, and perchance ſome ſmall particles of water; it is not eaſy to diſcover from whence this change of conſiſtence proceeds, unleſs from a change in the texture of the parts, whereby they are connected and diſpoſed after a new manner, fit to make them reciprocally hinder the freedom of each other's motions. But if, inſtead of hardening the whites of eggs by the heat of the fire, you beat them into a froth, you may perceive that froth to retain the nature of a ſtable body; for it may be raiſed up into a pyramid of a conſiderable height, And I have made, with a little care, a long and proportionably thick body of theſe bubbles, hang down like an iſicle from my finger, without falling: yet in theſe, there appears no alteration made in the fluid body, except a mere mechanical change of the diſpoſition of its parts: which may be confirm'd by water agitated into froth; for herein the bubbles will quickly ſubſide, and fall back into water, of the very ſame conſiſtence it was of before.

Several ways of producing this texture.

Now there are ſeveral ways, whereby a body may be put into a texture, proper to make it firm; tho', for the moſt part, one of them is not employ'd a-part, but two or more in conjunction. The firſt and chiefeſt of theſe, ſeems to be the fitneſs and ſhapes of the component particles, to faſten them to each other; as if ſome were figur'd like the handles of buckets, and others like the hooks employ'd to draw them; ſome like buttons, others like loops; ſome like male, others like female ſcrews: or, as if many together, were ſo variouſly branched, that their parts may be interwoven one within another, and not prove eaſily ſeparable; thus only by twiſting threads together, they are ſo well faſten'd to one another, as to conſtitute a cable, which is not to be broken without a vaſt force.

And

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PHYSICS. And ſo numerous may be the correſpondent figures, fit to faſten bodies to one another, that it is very poſſible for two fluids, upon their conjunction, to intangle their parts, and thereby acquire ſuch a new texture, that they cannot diſſociate themſelves, nor flow after the manner of liquors, but remain ſo connected, and unactive, as to become one entire firm body. Something like this appears, upon mixing the diſtill'd liquor of nitre, and that made *per deliquium* out of fixed nitre, which will thus preſently coagulate into ſaline and ſtable bodies. But this ſeeming only a reunion of the ſaline particles, that ſwam in the aqueous parts of the mixed liquor, which, after this ſeparation, remains both in greater plenty than the ſaline parts, and as fluid as before; we ſhall add another inſtance, to ſhew how much the firmneſs of bodies depends upon their texture. If you take, then, the rectified ſpirit of wine, and dephlegmed ſpirit of urine, and mix them in a due proportion, you may, in a minute, turn theſe two fluid liquors into a conſiſtent body; and, I have immediately, upon the ſhaking of them, ſeen them ſhoot like ſnow, and acquire ſuch a conſiſtence, that I could, without ſpilling the mixture, turn the veſſel upſide down. But this experiment will not ſucceed, unleſs both the ſpirits are exactly dephlegmed. Yet ſo much doth this coagulation depend upon the ſalt of urine, as being of a particular texture, and not as barely urinous, that ſufficiently rectified ſpirit of hart's-horn may be here uſed in its ſtead; tho' even a rectified ſpirit, drawn from unfermented urine, hath failed of producing the ſame coagulation. But it is farther remarkable in this experiment, that the white ſubſtance, being put into a glaſs-veſſel, exactly ſtopp'd, and kept in a gentle heat for ſome months, will, for the greateſt part, reſume the form of a limpid liquor; as if either all the crooked particles, that connected the ſmall coalitions, were, by this means, broken off; or the ſame little concretions, after various attempts to get clear of each other, at length extricated themſelves, and became able freely to ſhift their places, and form a liquor. And having digeſted a convenient proportion of pure *Saccharum Saturni*, made with ſpirit of vinegar, and rectified ſpirit of wine together, I found the mixture ſo changed in point of conſiſtence, that, upon inclining the containing veſſel, none of it would run down the ſides: yet, by the bare addition, even of a very fix'd and very dry body, this coagulum may, in a few hours, be reduced to a permanent liquor. But, becauſe it is not eaſy to procure ſpirits pure enough to make this experiment, we will ſet down another quick way of hardening one fluid body by another. If you beat the white of an egg, till it become thin, and then ſhake well into it, about half its quantity of true ſpirit of ſalt, the mixture will, in a few minutes, be ſo coagulated, that not a drop of liquor will run from it. Another experiment, of the ſame nature, we have from Sir *Francis Bacon*, of coagulating the whites of eggs with ſpirit of wine; and, by ſhaking the two ingredients well together, I have found it ſucceed. He ſuppoſes, indeed, that this coagulation proceeds from the heat of the ſpirit of wine; but that ſpirit, doubtleſs, abounds with a piercing ſalt, which may very well ſuffice for this pur-

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purpoſe. And we have not only produced the like effect with acid ſpirits, but even by a crude ſalt; for, by long beating the white of an egg, with a lump of alum, you may bring the greateſt part of it to a white curd. So that if we will allow this coagulation, to be performed by the heat of ſpirit of wine, this heat muſt be only ſuch, as may be aſcribed to the active particles of ſaline bodies, which yet are commonly accounted rather cold than hot. But becauſe I doubt how juſtly they are reputed ſo, I purpoſely took the ſerum of human blood, and endeavour'd, though in vain, to coagulate it with ſuch ſpirit of wine, as would coagulate the whites of eggs; yet this ſerum will coagulate by a gentle heat of embers, as ſoon as they: which makes it ſuſpicious, that the effect proceeded from the greater correſpondence in texture, of the ſpirit of wine, with one of the liquors, than with the other, rather than from the heat aſcribed to it, which did not at all coagulate the ſerum. PHYSICS.

Thus the eſſential oil of aniſeeds, which, in the heat of ſummer, remains as perfect a liquor as other chymical oils, contrary to them, during the cold of winter, coagulates into a body like camphire, and not without ſome degree of brittleneſs. We may add, that the liquor diſtill'd from benjamin, is ſubject to much more frequent viciſſitudes of fluidity and firmneſs; for part of it, all the year long, continues in the form of a blackiſh oil, and the reſt, according as the ſeaſon of the year, or the time of the day, makes the weather cold, or hot, frequently changes its texture; ſometimes appearing the ſame with the oil juſt mention'd; ſometimes ſhooting into clear, and variouſly-ſhaped cryſtals; which faſten themſelves to the bottom and ſides of the veſſel, till a warmer part of the day, or of the ſeaſon, diſſolves them again into a liquor. And this may alſo ſerve to confirm, that the fluidity of ſome bodies depends, almoſt wholly, upon the various agitation of their parts; for, in theſe inſtances, the parts of the aniſeeds, and thoſe of the benjamin, upon the operation, or abſence of the languid heat of the air, conſtituted a fluid, or a conſiſtent body.

And, as we have ſhewn, that two fluid bodies may be aſſociated into a conſiſtent one, ſo, on the other hand, a fluid body may, by the change of texture, be divided into two conſiſtent ones; as in drawing the more volatile parts of ſallad-oil, where neither the liquor that comes over, nor the ſubſtance which remains behind in the retort, is fluid, tho' the oil which yielded them were ſo. But before diſtillation, putting to the oil a convenient quantity of common ſalt, and another thing or two, fit to change the texture of the branched particles whereof it conſiſts, I then obtain'd an oil, that dropt into the receiver, in the form of a liquor, and continued fluid. I have, likewiſe, practiſed a way to purify the dark, muddy oil of amber, drawn *per ſe*, ſo that a large proportion of it would come over very tranſparent, and finely colour'd; and the liquor thus prepar'd, will ſwim even upon ſpirit of wine. My method is, to take two pounds of good brandy, one of ſea-ſalt, half a pound of the oil, and mix them, and diſtil them together.

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PHYSICS. Salt-petre, by being diſſolved in a ſufficient quantity of common water, will ſeem to be loſt therein; and to conſtitute with it, one uniform fluid ſubſtance; but, if a competent quantity of that water be exhaled, the ſaline particles, by re-uniting themſelves, form into ſtable cryſtals of determinate figures. Which will ſuggeſt a way, whereby ſome bodies may become firm and ſolid, by the admixture of a due proportion of water, or ſome other liquor. For though the ſmall parts of ſuch fluids, being themſelves in motion, are apt to communicate ſuch an agitation to others, as fluidity principally depends on; yet an equal, or a double weight of oil of vitriol, diſtill'd from running mercury, will, when far the greateſt part of the liquor is come over, leave a very white powder, conſiderably fix'd, behind it. And in preparing the beſt *Mercurius dulcis*, the quick-ſilver is ſo intermix'd with the ſalts it carries up in ſublimation, that the dry and brittle body they compoſe, may contain much more mercury than ſalt. And other experiments may ſhew, that the mixture of a convenient liquor may cement bodies into one hard concretion, which would ſcarce otherwiſe happen: for, different qualifications may be requir'd in a body, whilſt it is conſtituting, and when it is conſtituted. And though the motion of the parts that make it up, oppoſe the firmneſs of a formed body, yet it may conduce to make a firm body: for, when a great many hard corpuſcles lie together, looſe and incoherent, they reſemble a fluid; whereas, by the mixture of a liquor, thoſe looſe corpuſcles being, for a-while, diſſociated, and put into motion, they may, after many evolutions, apply themſelves to one another, after the manner moſt requiſite to make them touch in larger ſurfaces. Thus, in the burning of alabaſter, if the powder, after it hath done boiling, and been ſufficiently calcin'd, be well beaten ſome hours afterwards, and temper'd up with fair water, almoſt to a thin conſiſtence, that fluid ſubſtance will, in a few minutes, begin to exchange its fluidity for firmneſs; ſo that if it were before caſt into a mould, it will perfectly retain the impreſſion thereof. And that here there is, for a while, ſuch an agitation of the hard parts, produced upon the affuſion of the water, and afterwards an excluſion of the ſuperfluous water, appears from hence; that when any conſiderable quantity of burnt alabaſter is temper'd with water, the mixture ſoon grows ſenſibly hot, and ſometimes continues ſo for a pretty while: and having purpoſely fill'd a new half-pint vial with this liquid mixture, and ſtopp'd it up cloſe, in leſs than half an hour it crack'd the vial in ſeveral places, and diſcharg'd itſelf, at the creviſes, of about a ſpoonful of clear water; the remaining mixture retaining perfectly, the figure and dimenſions of the vial, and growing harder than chalk. And, let me add, that ſome other ſubſtances may thus afford much more ſolid bodies, than burnt alabaſter: whence it would be of good uſe to enquire what others are, by this means, reducible to a laſting ſolidity. *Fournier*, after having told us that the *Romans* made the faireſt harbours in the world, by the help of a certain ſand, to be met with at *Cumæ*, and *Puteoli*, in the kingdom of *Naples*, which, mix'd with a third part

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part of quick-lime, acquires, in the water, the hardneſs of flint, ſubjoins, that in *Flanders*, near *Tournay*, he ſaw a certain ſort of aſhes, made with marble-lime, that was excellent for any work in the water. For, having here made a bed of great ſtones, they caſt upon them large quantities of theſe aſhes, inſtead of mortar; and the water, betwixt the ſtones, having temper'd them up, ſo petrify'd them, that, in a ſhort time, they became as hard as marble. That the various motions, and juſtlings of the hard particles, conduces to their uniting into one ſtable concretion, ſeems confirm'd, by what we have obſerv'd in ſome ſaline liquors, eſpecially certain parcels of ſpirit of hart's-horn, which, whatever were the conſtitution of the ambient air, remain'd fluid, ſome of them for many months; after which, the ſaline corpuſcles began to ſhoot, at the bottom of the remaining liquor, into exquiſitely figur'd cryſtals. For this ſpontaneous coagulation, happening ſo late, ſeem'd to be preceded by numerous evolutions; whence, at length, the little bodies came to turn thoſe parts of themſelves to each other, by which they might be beſt faſten'd together, and conſtitute a firm body. For this coagulation proceeded not from the evaporation of the ſuperfluous liquor, becauſe the glaſſes were carefully ſtopp'd; and if any thing could get away, it muſt have been a ſubtile ſpirit, which would only have left the remaining liquor more aqueous: and it is well known, to thoſe who deal with ſuch kinds of liquors, that the more aqueous they are, the leſs they tend to cryſtallize. And, having in a cryſtal vial, carefully kept a quantity of well-colour'd tincture of amber, made with pure ſpirit of wine, it remain'd fluid for a year or two; but, after two or three years more, I found ſeveral yellow lumps of amber, almoſt like beads, with one ſide flat, here and there faſten'd, partly to the bottom, and partly to the ſides of the glaſs.

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Adventitious particles may conduce to firmneſs.

Another cauſe of ſtability in bodies, is, the admiſſion of adventitious corpuſcles into their pores: of the ways wherein this may happen, theſe appear to be the chief. 1. By expelling thence thoſe voluble particles, which, by their ſhape, or motion, oppos'd the coalition, or diſturb'd the reſt of the other particles, whereof the body conſiſted. 2. By hindring the motion of the little bodies that compoſe it. And, 3. By conſtituting with the particles it conſiſts of, corpuſcles more unapt for motion, and fit for mutual coheſion. To theſe ſeems reducible the way of coagulating milk by runnet, whoſe ſaline particles pervading the body of that fluid, not only make a commotion in the parts of it, but faſten the branched particles thereof to one another, and, with them, conſtitute a body of another texture: when the weight of theſe curdled bodies, reducing them, by degrees, into a cloſer order, ſqueezes out the thinner liquor, which the runnet was unable to coagulate; and which, being thus ſever'd from the groſſer parts of the milk, may well be more fluid than the milk itſelf. And that there is ſome coalition of the particles of the runnet, with the coagulated ones of the milk, appears by the complaints made of cheeſes taſting too ſtrong of the runnet. And tho' we here aſcribe the coagulation of milk, to the ſaline particles of runnet, yet oil of vitriol, the juices of ſeve-

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PHYSICS. ral herbs, and other things, will do the ſame. I have prepared a ſalt of the ſame nature with the *Sal mirabilis* of *Glauber*, which ſeem'd to have a power of coagulating common water; for, being diſſolv'd in a convenient quantity of it, almoſt the whole mixture will ſhoot together into fine cryſtals, apparently of an uniform ſubſtance, and ſo brittle as to be pulverable; tho' the concretion may have ſuch a proportion of water in it, that when the experiment has ſucceeded well, I have, from three parts of water, and but one of ſalt, had about four parts of cryſtals. I have alſo prepared a whitiſh ſubſtance, which would not only deſtroy the fluidity of ſome other liquors, but give a conſiſtence to a large proportion even of oil of vitriol; the parts whereof are ſuppoſed to be vehemently agitated. And at the bottom of a well-ſtopp'd vial, I have kept a little of this powder under a conſiderable proportion of oil of vitriol, which appear'd conſiſtent, without having affected the powder, whereon it had been only poured, and ſuffer'd to ſtand in the cold for a day or two. And if upon whole cryſtals of nitre, very well dried, and contain'd in a vial, you gently pour good oil of vitriol, till it ſwim about half an inch above the ſalt, and leave the vial cover'd with paper, at reſt, in a cool place; the liquor will, if the experiment ſucceed, ſlowly ſettle itſelf about the nitre, ſo that the vial being inclined, it will not run out. And that in coagulating quick-ſilver, by the vapour of melted lead, ſome metalline fumes really enter the quick-ſilver, ſeems probable, from the waſting of lead by fuſion, and the effects aſcribed by chymiſts to the fume of lead upon gold. And a phyſician of my acquaintance, keeping ſome lead long in fuſion, to reduce it *per ſe* into a calx, and holding his head often over the melting-pot, to obſerve the alterations of the metal, was ſuddenly purged ſeveral times upwards and downwards; which both he and I aſcribed to the metalline exhalations. And tho' I ſuſpected the congelation might proceed from the loſs of ſome ſubtile ſubſtance, that formerly agitated, but after deſerted the mercurial corpuſcles; yet that the concretion of the quick-ſilver might be effected by ſome benumbing vapour of the lead, ſeems confirm'd by an obſervation of that great geometrician, Dr. *Wallis*, and others at *Oxford*; who in making the experiment under conſideration, found, that upon the firſt fuſion of the lead, the quick-ſilver being tied up in a rag, and, before it grew too cool, immers'd therein, was very well coagulated by it; but when they came to melt it the ſecond time, and put other quick-ſilver into it, the experiment would not ſucceed: which ſeems to prove, that there is in lead a coagulating ſteam, or ſpirit; but in ſo ſmall a proportion, that it almoſt totally diſlodges, or ſpends itſelf, upon the firſt opportunity it meets with, of paſſing into quick-ſilver. Pouring ſome common ſallad-oil upon *Aqua fortis*, it at firſt floated together on the top of it, but after ſome hours, had its texture ſo chang'd, by the aſcending ſteams, that it was turn'd into a white conſiſtent body, reſembling butter. The like we have perform'd with expreſſed oil of ſweet almonds. And ſome times pouring off the ſame *Aqua fortis*, or ſpirit of nitre, wherewith I had coagulated oil-olive, from the butter-like ſubſtance, I have caſt camphire into

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into it, which, without heat, was thereby reduc'd to an oil, retaining a distinct ſurface from the menſtruum whereon it floated; ſo that the ſame menſtruum, unaſſiſted by fire, turn'd a brittle body into a liquor, and *vice verſâ*; for common oil ſuffer'd to float long enough upon it, will be brittle. And this brittle ſubſtance, ſeem'd to receive a more durable alteration from the menſtruum, than we expected: for, when melted with heat, it would, upon cooling, become again conſiſtent; and I could not reduce it to a liquor, by mixing it with oil of tartar *per deliquium*; which has a great power to mortify acid ſpirits, ſuch as *Aqua fortis*, and ſpirit of nitre. The laſt way whereby external corpuſcles, entring into a body, may give it a ſtable conſiſtence, is, by cauſing ſuch a commotion in the parts of it, as may make them apply themſelves one to another, in a greater ſurface, or otherwiſe complicate and diſpoſe them after the manner requiſite to make them ſtick together. This way of rendring bodies conſiſtent, is ſeldom or never employ'd by nature, without the concurrence of ſome of the other means already mention'd: but we have diſtinguiſh'd it from the two laſt, becauſe, in them, we ſuppoſe ſome of the adventitious corpuſcles to be ſtopp'd in the body, to whoſe firmneſs they conduce; but here we ſuppoſe, that without materially concurring to conſtitute the body they work on, they only agitate, and variouſly move the particles it conſiſts of; ſo that the parts, which formerly either mov'd ſeparately, or adher'd together but looſely, are now reduced to a cloſer order, or more implicated texture, and thereby more firmly connected to one another. That the bare diſpoſition of the parts of a body, with regard to each other, without any addition of foreign matter, will greatly conduce to ſtability, we may ſee both in ſome examples formerly mention'd, and in oſier wands, which, when lying looſely in a heap together, may each of them very eaſily be diſſociated from the reſt; but, when they are breaded into a baſket, they cohere ſo ſtrongly, that if you take up any one of them, you raiſe all the reſt. We might add thoſe many obvious inſtances, wherein, by the bare texture of the ſlender hairs, or threads whereof wool or ſilk conſiſts; cloth, ſtockings, and many other durable garments, are made. We may, alſo, obſerve the force of bare motion, in altering the texture, and, thereby, the conſiſtence of bodies in the common way of churning: for there the external impulſe, makes a great commotion in the parts of the cream; whence the more branched corpuſcles, meeting with one another, are intangled, and thereby ſeparated from the reſt: and, after many occurſions, all theſe parts are, at length, faſten'd to one another; and excluding thoſe of the thinner fluid, which ſeem not ſo conveniently ſhaped for mutual coheſion, conſtitute butter; which is made yet more conſiſtent, or compact, by being compreſs'd, as the parts thereby reduced into a cloſer order, ſqueeze out the liquor which was intercepted amongſt them. It will, perhaps, be thought more ſtrange, that a fluid body, nay, a diſtill'd liquor, which is very volatile, and paſſes for ſimple, and homogeneous, ſhould, by motion, without the mixture of any new matter, be made coherent; yet, even the chymical oil of turpentine, may, in a great meaſure, if not wholly, be coagulated without

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PHYSICS. without addition. A very expert chymiſt ſhew'd me, in a receiver, ſome oil of turpentine, which he had often diſtill'd over *per ſe*, very much coagulated into a whitiſh and conſiſtent body; affirming, that he had, ſometimes, by frequent diſtillations, without addition, obtain'd from clear oil of turpentine, a far greater proportion of ſuch a ſtable ſubſtance; whoſe conſiſtence, whether it ſhould be aſcribed to the fire's breaking the oily corpuſcles into parts more fit for mutual coheſion; or whether it proceed from a new texture of the ſame corpuſcles, happening from thoſe various evolutions, to be diſpoſed after ſuch a manner, as to complicate, or otherwiſe connect them, I need not now enquire: it is ſufficient, that we hence ſee how much even motion, without the addition of any ſenſible ſubſtance, may, in ſome caſes, conduce to firmneſs. I have obſerv'd, that oil of wax, diſtill'd in a retort, with a proper addition, tho' at firſt it chiefly came over in the form of a butter, yet, by ſtanding in a cool place, and in cool weather, it would gradually reſolve into a tranſparent oil.

Firmneſs may be the reſult of a particular texture.

But what if fluidity and ſtability depend ſo much upon the texture of parts, that by the change of that texture, the ſame parts may be made permanently to conſtitute either a fluid, or a dry body? An inſtance of this is afforded us by quick-ſilver; for, if ſome ounces of that fluid mineral, be put into a convenient glaſs-veſſel, and that veſſel be firſt exactly ſtopp'd, and kept for ſix, eight, or ten weeks, in a ſand furnace, whoſe heat may be ſtrong and conſtant, the corpuſcles that conſtitute it, will, after innumerable revolutions, be ſo connected to one another, that inſtead of a fluid body, they will appear in the form of a red powder, which chymiſts call precipitate *per ſe*. But to do this more expeditiouſly, take half a pound, or a pound of quick-ſilver, and, with a ſtrong fire, diſtil it out of a glaſs retort; and, for the moſt part, there will remain in the bottom, and about the ſides of the veſſel, a little red powder, which ſeems to be nothing but part of the fluid body turn'd into a dry one, in eight or ten hours time. After what manner the fire produces ſo odd a change in the quick-ſilver, I preſume not to know. It is true, that tho' the corpuſcles of liquors touch one another but in part of their ſuperficies, yet they all of them ſeem to have ſome degree of viſcoſity, ſlight complication, or adheſion of parts; as appears by their being ſo eaſily reduced into thoſe thin membranes, or films, which we call bubbles: ſo that not only ſpirit of wine will afford them, but even quick-ſilver, notwithſtanding its ponderoſity, being ſuffer'd to fall in a ſlender ſtream, into a veſſel almoſt full of the ſame mineral, yields numerous and large bubbles, though they are not laſting. Hence it might be imagin'd, that in this operation, ſome ſuch change is made in the quick-ſilver, as we formerly obſerv'd in the white of an egg; when, a new diſpoſition of its parts, cauſed either by heat, or concuſſion, makes it a kind of ſtable body: or elſe it may be argued, that there is a variety of parts, in quick-ſilver, from the great variety of its effects upon other bodies; and that by the frequent evolutions, which the fire makes of thoſe parts among themſelves, they come, at length, to be ſo

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ſo applied to one another, as either to lock into each other, or ſlip upon one another's ſurfaces, ſo that as much of their ſurfaces immediately touch, as is requiſite to make them cohere. Theſe conjectures, and many others, may be propoſed, but, I fear, all of them will not ſolve the phenomenon. Nor were we much inſtructed, from viewing our mercurial precipitate in an excellent microſcope: we hence only diſcover'd, that the red powder had in it many corpuſcles of various other colours; and that the little grains had no determinate ſhape, but appear'd like ſlender fragments of red coral. And having put ſome ſmall duſt of a ſhining precipitate of gold and mercury, into the ſame glaſs, all we could diſcern was, that the little grains of this, differ'd from thoſe of the other; being ſo tranſparent throughout, that any one would have thought he beheld the beſt ſort of thoſe precious ſtones call'd granats. But tho' we pretend not to ſhew, how the new texture is produced in the quickſilver, yet to make it ſtill more evident, that its change of conſiſtence proceeds from its change of texture, we will add, that having a deſire to try whether our powder could not be made fluid again, I procur'd ſome precipitate *per ſe*; which being weigh'd, and put into a convenient glaſs, was carefully urged with a naked fire; and, at length, it roſe, by degrees, in fumes, which ſettled in the neck of the glaſs, in many drops of running mercury; all which, being collected into one, we found that there wanted but about a ſixth or ſeventh part of what we had put in; and, perhaps, we had not wanted that, only the vehemence of the fire melted the glaſs, which took up ſo much of the powder, as made a great ſhew thro' it, after we had remov'd what was fuſed, from the fire. Having half an ounce of a certain mercury, which I took for that of lead, I found I could, barely by ſhaking it long together, reduce it to a black powder; in which form it would continue as long as I pleas'd: and barely by dextrouſly rubbing it in a marble mortar, I could immediately reduce it to a running mercury again; which quick paſſage from one to another, being made without the help of fire, or without adding, or taking away any viſible ſubſtance, ſhews how greatly motion and reſt, and the texture of the component parts of matter thence reſulting, may contribute to fluidity and firmneſs. Hence we learn what to think of the doctrine of ſome modern philoſophers, who teach, that a fluid body is always diviſible into bodies equally fluid, as quantity is into quantities; as if the particles of fluid bodies muſt alſo be fluid themſelves: for, it appears, that quick-ſilver, and ſome other actually fluid bodies, greatly conſiſt of hard corpuſcles, ſince, by the change of their texture, they may be depriv'd of their fluidity, and become ſtable. We ſee, alſo, that the ſtiff and ſolid particles of ſalts, diſſolved in common water, and of ſilver diſſolv'd in *Aqua fortis*, being, by thoſe liquors, ſufficiently diſſociated, and ſeparately agitated, with them conſtitute fluid bodies. And, by putting together, in a glaſs retort, one part of quick-ſilver, and four of common oil of vitriol, and diſtilling them in a ſand furnace, with a ſtrong fire, there remain'd in the bottom of the veſſel, a ponderous calx, ſo far from fluid, that it was but in part diſſoluble in water. And what ſeems to prove, that, in.

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The chymical notion of ſtability, &c. exam'd.

From what is here deliver'd, we may alſo be aſſiſted to judge of the doctrine of the chymiſts, who teach, that in all bodies, coagulation, ſtability, hardneſs, and brittleneſs, depend upon ſalt; for tho' what has been ſaid of the curdling of milk by ſaline liquors, and the hardneſs obvious in ſalts

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ſalts themſelves, may keep us from denying, that the ſaline principle is very powerful in the coagulation of ſome bodies, that is, produces much firmneſs, or even brittleneſs, in many of the concretes wherein it is predominant; yet this hardeniug power ſeems not to proceed from any peculiar property to coagulate other bodies, or make them compact; but from the ſhape and motion of its corpuſcles, which, it ſeems, are more fitted by nature, than thoſe of many other concretes, to inſinuate themſelves into the pores of bodies, and faſten their particles to themſelves, and to one another; as when many pieces of paper are kept from ſcattering, by a wire run thro' them. But whenever there is in the conſtituent parts of a body, a ſufficient fitneſs and diſpoſition to adhere firmly to one another, nature may of thoſe parts compoſe a ſtable body, whether they abound in ſalt, or no; it not being ſo much upon chymical principes, or even upon the predominancy of any one ingredient, as upon the ſhape and motion of the component parts of bodies, that their fluidity and firmneſs depend. I will not here urge that ſalts are generally reducible by an eaſy mixture with water into the form of liquors; nor that ſea-ſalt, ſalt of tartar, and many other ſorts of ſalts, will, of themſelves, even in the air, aſſume the form of fluids; nor yet will I preſs the example of coral, which is confidently affirmed to be ſoft, whilſt it remains in the ſalt water, and to grow hard when taken out of it: but I ſhall rather demand, what ſalt can be made appear to paſs out of the body of melted lead into that of quick-ſilver, to perform in it the coagulation above-mentioned? What acceſſion of ſalt is to be obſerved, when running mercury is precipitated *per ſe* into a powder? And how will it be proved, that when, in a well-ſtopped glaſs, the whole body of water is, in froſty nights, turned into firm ice by the cold of the air, that coagulation is performed by ſalt: for chymiſts have not yet made it appear, that either ſalts, or even the diſtilled ſpirits of them, can penetrate, without a kind of prodigy, the narrow pores of unheated glaſs? It is uſually obſerved in eggs, that tho' at their being firſt laid, the ſhells are ſoft, yet they ſoon after grow hard and brittle; yet it appears not how the ſaline ingredient is increaſed, to effect this ſpeedy induration: and tho' the coldneſs of the outward air, and its imbibing ſome of the moiſt parts of the ſoft ſhells, may concur herein; yet there are many obſervations of egg-ſhells, found hard in the hen. And I myſelf have found ſeveral eggs, at one time, in the body of the ſame hen, which were each of them furniſhed with a compleat and brittle ſhell. I farther demand, what quantity of ſalt can pierce the hard ſhell, and cloſe-wrought membrane, that both lines it, and involves the egg, eſpecially ſince eggs may be hatched by a temperate external heat without the hen? Yet we may here obſerve, that the ſame internal ſubſtance of the egg, which at firſt was fluid, is, upon the excluſion of the chick, turned, almoſt wholly, into conſiſtent bodies, ſome of them tough, as the membranes and griſtles of the bird; ſome of them harder, and almoſt brittle, as its bones and beak; and all this without the acceſſion of new ſalt. It would be difficult for chymiſts to prove, that diamonds and rubies contain ſalt: and it may be alſo queſtioned, whether

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PHYSICS. the blood of animals, when it is freeſt from ſerum, does not, tho' a liquor as much abound with ſalt, as their ſkins or fleſh.

And ſince it is with chymiſts that I now argue, I farther demand of them, whence it happens that one grain of the powder of projection can turn a whole pound of mercury into true gold or ſilver; and, conſequently, change a very fluid body into a very firm one; tho' the proportion of ſalt employ'd, would not amount to the ſix or ſeven thouſandth part of the liquor. To this I ſhall add, what *Helmont* relates upon his own experience, and that of *Raymond Lully*, concerning his alkaheſt, that, being abſtracted from common quick-ſilver, it, in a quarter of an hour, coagulates it, yet leaves nothing of itſelf with the mercury on which it works. I remember alſo, that a phyſician of great veracity told me, that at the Duke of *Holſtein*'s he took notice of a glaſs of ſpirit of urine, which in warm weather remained in the form of a liquor, but was in cold weather totally coagulated into cryſtalline ſalt; in the preparation of which, he ſaid, the Duke cauſed ſpirit of urine, exceeding rich in volatile ſalt, to be very often diſtill'd; after every diſtillation uniting all that came over in a liquid, with that which remain'd in a ſaline form, till by very frequent cohobations, all the parts of the urinous ſubſtance were brought to the coalition above-mentioned.

And on this occaſion, we will annex a few other particulars, tending as well to render the chymical hypotheſis doubtful, as to confirm our own. And firſt, in the art of making ſugar, very great care is taken, that nothing acid fall into the caldrons, (eſpecially the juice of lemmons) wherein the juice of the ſugar-cane is to coagulate: for tho' acidity be generally by the chymiſts aſcribed to ſalt, yet theſe ſaline bodies are here ſo far from promoting the coagulation of the ſaccharine ſyrup, that they would utterly prevent it. To the authorities of *Piſo*, and others, for this, I might add what has been confirmed to me by perſons who pretend more than ordinary knowledge in the art; but all agree, that the juice ſqueezed out of the ſugar-canes is firſt boiled, and purified in vaſt veſſels of copper or braſs, whence it is afterwards convey'd to be farther purified and coagulated in ſmaller; and that whilſt it is in the former, they pour upon it ſome very ſtrong lixivium to facilitate the ſeparation of its feculencies; as in the ſmall ones, it is uſual to pour a little oil or butter, upon the boiling juice to keep the ſyrup from boiling over. They farther declare, that if the oil were added to the liquor in the larger veſſels wherein it is firſt clarified, or the lixivium put to it in the ſmaller, in either caſe, it is abſolutely impoſſible to make ſugar. So greatly do the fluidity and firmneſs of bodies depend upon their texture, how much ſoever the chymiſts would have them depend upon ſalt.

To this borrowed obſervation, we will add two or three experiments of our own, made on purpoſe to give light into this matter. Firſt then, we prepared a liquor as ſaline as *Aqua fortis*, and yet when we laid fragments of ſolid hart's-horn of ſeveral ſizes to ſteep in it, the menſtruum was ſo far from hardening, that it would pierce into and ſoften them; ſo that in about two or three days, it reduced them to a kind of white mucilaginous ſubſtance. We took, alſo, good ſalt of tartar, and poured on it ſpirit of vinegar,

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negar, as long as the affuſion would produce any ebullition; then we diſtill'd off the liquor, which came over almoſt inſipid; the ſaline parts which make the ſpirit of vinegar ſo ſharp, being retained by the ſalt of tartar: upon the remaining dry mixture, we poured freſh ſpirit of vinegar, as long as any hiſſing enſued, and afterwards abſtracted the aqueous parts of this parcel of liquor alſo; and ſo we proceeded, till having ſufficiently impregnated the fixed ſalt with the ſaline parts of the diſtill'd vinegar, we obtained a mixture, which, tho' wholly conſiſting of ſalts, required not the heat of the fire to turn it into a liquor. Laſtly, we took common oil of vitriol, and caſt into it ſeveral little pieces of camphire, which floating upon it, were by degrees, in ſome hours time, wholly reduced into a reddiſh oil, which appeared together upon the top of the other liquor: then, having formerly found, that oil of vitriol would eaſily mix with common oil, we tried alſo, by ſhaking the ſaline and camphorate liquors together, to unite them, and eaſily confounded them into one high-coloured liquor, which ſeemed very uniform, and continued ſo for many hours; then we added to this mixture three or four times as much fair water, and the camphire immediately became a white conſiſtent body again, and by degrees ſettled at the top of the liquor: where we may obſerve, that the camphire is not made hard, but fluid, by mixing with the ſaline corpuſcles of oil of vitriol; and that it exchanges its fluidity for firmneſs upon the effuſion of inſipid water. PHYSICS.

And thus much may ſuffice to have ſaid of the ſtability of bodies from ſalt. As for the hardneſs and bittleneſs which the chymiſts alſo aſcribe to the ſame principle, how much they may be increaſed or diminiſhed, without the addition or decreaſe of the ſaline ingredient, appears in the experiment of tempering a ſlender piece of ſteel: for when this hath been ſufficiently heated, you may, by plunging it red-hot into fair water, which is more likely to diſſolve than increaſe its ſalt, make it both very hard and very brittle; but by too leiſurely cooling in the air, it will become much leſs hard, and more tough: and if, after having quenched it in cold water, you again heat it, till it have attained a deep blue, it will become ſoft, and very flexible; and that not from any waſte made of the ſaline ingredient by the fire: for if this ſoften'd ſteel be again heated red-hot, and ſuddenly cooled, whether in water, or otherwiſe, it will regain both hardneſs and brittleneſs. And that by procuring a cloſer order, and more immediate contact of the parts of a body, we may, without increaſing the ſalt, increaſe the hardneſs of it, is alſo obvious from compreſſing ſnow, as was formerly obſerved.

I know that ſeveral philoſophers, entirely aſcribe the induration, and eſpecially the petrifaction of bodies, to a ſecret internal principle, by ſome of them called a form, and by others a petrifying ſpirit, lurking commonly in ſome liquid vehicle; and from conſidering ſeveral cryſtalline bodies, and regularly-ſhaped ſtones and other minerals, which I have ſeen and known to be dug out of the earth, I am forward to grant, that it is a plaſtic principle implanted by the wiſe creator in certain parcels of matter, which produces in ſuch concretions, as well the hard conſiſtence, as the determinate figure. But the difficulty conſiſts in conceiving how that internal principle produces

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PHYSICS. its effects; which theſe writers not pretending intelligibly to explain, we thought proper to ſurvey ſome of the principal ways, by which nature ſeems to make bodies firm and ſtable; whence we may be aſſiſted to judge whether it is neceſſary to have recourſe to a plaſtic principle, or petrifying ſpirit, in the hardening of ſuch bodies, whoſe curious and determinate textures argue their having been faſhioned by ſome one formative power, or by ſeveral ſeminal principles convened together. And becauſe hardneſs is a high degree of firmneſs, we ſhall ſhew by ſome examples, how ſmall an external operation may, without any apparent adventitious ſalt, render a ſoft body hard, and even brittle, when there appears no other change to be made, than in the texture or diſpoſition of its component particles.

It is a tradition that coral grows ſoft at the bottom of the ſea; but when it is brought up into the open air, tho' it retains its bulk and figure, yet it then hardens into a ſtony concretion; according to that of *Ovid*,

Sic & corallium quo primum contigit auras
Tempore, dureſcit; mollis fuit herba ſub undis.

Now as to the truth of this tradition, *Gaſſendus*, in the life of *Piereskius*, has this paſſage concerning that gentleman's fiſhing for coral near *Toulon*: "The plants which were plucked up, appeared neither red nor beautiful, "till their bark was taken off; in ſome parts they were ſoft, and would "give way to the hand, as towards the tops, which being broken and "ſqueezed, they yielded milk like that of figs." *Fournier* likewiſe, after having particularly deſcribed the way of fiſhing for coral near *Toulon*, adds, "theſe plants are neither red nor ſmooth when drawn out of the water, "till their rind has been taken off; nay, they are ſoft, and being ſqueezed "between the fingers, throw out a kind of milk reſembling that of figs: "and when the preſſure ceaſes, the ſmall holes or pores, that harboured "the milk, are viſible*." The credibility of theſe accounts has been confirmed to me by a phyſician, who, in his return from the *Eaſt Indies*, having made ſome ſtay on the iſland of *Mehila*, near that of *Madagaſcar*, where white coral is reported to grow in plenty, aſſured me, he had often gathered coral upon the ſand of that iſland, and found it, when firſt taken up, exceeding white, and (to uſe his own expreſſion) as ſoft as an onion; adding, that tho' it would ſoon grow hard in the air, yet if it be not gathered at a ſeaſonable time of the year, it will not keep long, but either crumble away, or otherwiſe decay. And *Piſo*, in his natural hiſtory of *Braſil*, ſpeaking of

* M. *Geoffroy* tells us, that Count *Marſigli* ſatisfied himſelf, coral was a plant, by placing it, when newly fiſhed up, in ſea-water; where, after ſome time, he perceived that the little red tubercles upon the ſurface of its bark gradually expanded, and, at length, appeared in the form of white flowers, ſtar-faſhioned, with eight points, and a ſmall calix divided into eight parts: but taking the branches out of the water, theſe flowers preſently cloſed up, and formed themſelves into red tubercles again, which being ſqueezed, afforded a milky juice. Putting the branches again into ſea-water, theſe tubercles flowered again, and continued thus for eight or ten days. *Memoir. de l'Acad. An.* 1708. p. 130.

places

places upon that coaſt, where many ſtony plants, ſome like little trees, ſome otherwiſe figured, may be ſeen in clear weather growing at the bottom of the ſea, tells us, that if they are plucked up from the bottom, they preſently, by being expoſed to the ſun upon the ſhore, become exceeding hard, dry, and white. And *Scaliger* tells us, upon his own knowledge, of a ſhining matter voided by urine, which in the air coagulated into a firm ſubſtance like glaſs. It is, alſo, affirmed of amber, that it hardens in the air after being dragged out of the ſea; which ſeems the more credible, becauſe I have ſeen a whole ſpider perfectly incloſed in a piece of hard and tranſparent yellow amber. It is not impoſſible, that the contact of the external air may put the parts of ſuch ſmall bodies into a new motion, whereby ſome voluble corpuſcles, which hinder their reciprocal adheſion, may be excluded, and the particles themſelves preſs'd, or otherwiſe diſpoſed into a cloſer order: and we find, that ſome oil-colours, after they are brought to their due temper, may be preſerved very long in the ſame degree of ſoftneſs, if they, and the ſhells that contain them, be kept all the while under water; tho' in the air, they would quickly change their texture, and become dry and hard. But tho' in the laſt example, the removal of a body out of the water into the air, ſeems manifeſtly to contribute towards its growing hard; yet it is not ſo eaſy to determine, what ſhare the air hath in effecting ſuch indurations: for *Gaſſendus* relates of *Piereskius*, that it being his cuſtom in the ſummer time to waſh himſelf in one of the leſſer ſtreams of the *Rhoſne*, he there once felt the ground, which he uſed to find even and ſoft, grown hard with little round balls, like hard boiled eggs without their ſhells; ſome of which he took up, carried home, and in a few days after, returning to the river, he found thoſe little balls or lumps turned into perfect pebble-ſtones; which he obſerved likewiſe befel thoſe which he had carried away, and laid up. I have known two or three ſpoonfuls of burnt alabaſter, mix'd up thin with water, in a ſhort time coagulate at the bottom of a veſſel full of water, into a hard lump, notwithſtanding the water that ſurrounded it; which, it ſeems, by the texture of the maſs, was kept out of its pores, as it is out of thoſe of the oils of cinnamon and cloves, which, tho' fluid bodies, that will ſink in water, ſuffer not its particles to inſinuate themſelves between theirs: and artificers obſerve, that the coagulating property of burnt alabaſter will be very much impaired or loſt, if the powder be kept too long, eſpecially if in the open air, before it is made uſe of; and when it hath been once temper'd with water, and ſuffer'd to grow hard, they tell me, they cannot, by any burning or powdering of it again, make it ſerviceable for their purpoſe as before: ſo much doth the coagulation of theſe powders, mixed with water, ſeem to depend upon their texture, and other mechanical qualities. I remember alſo, that tho' the bones found in the hearts of deer, ſo extoll'd by phyſicians, do, in the air, acquire a hard conſiſtence; yet having conſider'd one of them in the heart of a deer newly kill'd, I found it there of a cartilaginous ſoftneſs and flexibility. And I have often doubted, whether not only conſiſtent bodies, but ſome of the moſt ſolid, may not have been fluid in the form either of ſteams

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PHYSICS. or liquors, before their coalition into ſtones or other mineral bodies. There are many who think, that ſtones, marcaſites, and ſuch other durable bodies, were made together at the creation; and will not admit, that ſuch concretions can now be generated: tho' it would not be difficult to ſhew, that ſuch parcels of matter are now to be met with in the form of ſtones, as did not before appear under that form; but whilſt it was divided into minute parts, either was itſelf ſome fluid body, or at leaſt did, as a material part, concur to conſtitute one that was ſo. I have ſeen a flat ſtone, in which was moſt lively ingraven the figure of a ſmall fiſh, with all the fins, ſcales, *&c.* which was affirmed to have been incloſed in the body of that ſtone, and to have been accidentally diſcovered, when the ſtone, chancing to receive a blow upon its edge, ſplit aſunder. A ſervant of mine, in the country, inform'd me, that whilſt he cauſed one of my walls to be repaired, the maſon breaking a ſtone to uſe about the building, found in it a piece of wood, which ſeem'd part of the branch of ſome tree. And this appears to me a more cogent proof of the increaſe of ſtones, than ſeveral others, on which eminent naturaliſts rely.

And unleſs we will ſuppoſe, there were, from the beginning, made together with, or in the midſt of great maſſes of one kind of mineral, little parcels of another, of a quite different ſort, either whole quarries of ſtone, or heavy and ſhining minerals, or both, may have been fluid bodies. The obſervation whereon I ground this conjecture, is, not only that we have met with in lead-ore, and alſo in *minera antimonii*, parcels of a white ſtone, or ſpar, ſurrounded with a metalline body; but chiefly, that I have, with my own hands, taken a hard, ponderous, ſhining mineral, like a marcaſite, of the ſhape of a pear, and of about the bigneſs of a walnut, out of the very body of a ſtone which environ'd it on all ſides; and this I took, not out of a ſmall and looſe ſtone, but a large one, dug for ſtatues. And one of thoſe who wrought upon it, told me, that in faſhioning it into ſtatues, they found it contain more minerals. And a ſtatuary, having taken much pains to ſaw aſunder a very large ſtone, when he came to the middle of it, found he could go no farther; the ſtone being broken, he perceived, that what ſo obſtinately reſiſted his ſaws, was a round marcaſite, which he brought me; but I cauſed him, for my ſatisfaction, to bring alſo that part of the ſtone, wherein the marcaſite lay, and by comparing them together, I diſcern'd, that as much of the ſtone, as was contiguous to the marcaſite, had a kind of ruſt about it, and fitted the marcaſite ſo cloſe, as if either that had been formerly liquid, and afterwards, as it were, moulded in its receptacle, or the ſtone had been originally of ſome ſoft or fluid matter, which exactly accommodated itſelf to the ſhape of the other body; or, laſtly, as if both the matter of the ſtone, and that of the marcaſite, had been at once fluids; each preſerving its own ſurface diſtinct, till one of them firſt growing hard, the other, as being yet of a more yielding conſiſtence, accommodated itſelf to the figure of the former.

But the moſt eminent inſtances, to manifeſt how much the fluidity and firmneſs of bodies depend upon the texture of their parts, are afforded by thoſe

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thoſe waters, which, being permitted to reſt a-while, ceaſe to be fluid, and coagulate into ſtone. An ingenious man, lately going to viſit ſome lead-mines, wherein he had a ſhare, found in the mountain, where they were hid, a cave, from whoſe arched roof, there dropp'd down a petreſcent liquor, which often congeal'd, before it could fall to the ground, and by the appoſition of like matter, increaſed ſo much, as to hang from the roof, like iſicles, from the ſides of a houſe; and of theſe he gathered, and brought me ſeveral, which are perfect ſtones, hard and brittle, eight or ten inches long, and proportionably thick. Another friend of mine, being lately in the cave, ſo famous for its petrifying liquor, in *France*, and obſerving ſome drops of water to congeal into ſtone, whilſt he ſtood by, took them away with him, and ſent them to me. And we ſhall ſcarce deny, that an external agent, of an almoſt inſenſible bulk, may turn animal bodies into ſtones, by introducing a new texture into their parts, if, with ſome modern writers, we credit *Aventinus*, who, in his *Bavarian* hiſtory, records, that at a certain time and place, above forty men and women, with their cattle, killed by an earthquake, had their bodies, by a terrene ſpirit, turned into ſtatues; which, he ſaith, were ſeen by the chancellor of *Auſtria* and himſelf. And we meet with ſome relations of this nature in other authors, which, if allow'd, will much confirm our doctrine; for in theſe ſtrange petrifications, the hardening of the bodies ſeems to be effected principally, as in the induration of the fluid ſubſtances of an egg into a chick, by altering the diſpoſition of their parts; ſince the petrifying ſteam cannot be ſuppoſed to have any ſuch conſiderable proportion in bulk, to the body changed by it, as to effect this change chiefly as an ingredient. We may add, that *Pamphilio Piacentino* is, by another author, quoted for an unparallel'd account of a woman in *Venice*, who, after having eaten an apple, ſuppoſed to have been poiſon'd, was ſeized with hideous tortures, and dying in the ſpace of twenty-four hours after, was turned into exceeding hard ſtone. But leſt we ſhould ſeem to build upon the obſervations of others, which cannot be now brought to ſtrict examination, we will produce a practicable experiment of our own.

Take then two ounces of quick-ſilver, two ounces and a half of the beſt verdigreaſe, about half an ounce, or an ounce, of common ſalt, a pint, or pound, of white-wine vinegar, and as much fair water; incorporate the verdigreaſe, quick-ſilver, and the ſalt, very well, and put the mixture, with a little of the vinegar and water, into a new pan, and fry it over the fire for ſeveral hours, keeping it continually ſtirred, and putting in more vinegar and water from time to time, as that already put in conſumes: then take out the mixture, and, in ſeveral clean waters, waſh it carefully from the adhering ſalts, and dry up the aqueous moiſture with a clean linen-cloth; whereby you will have a bright amalgam, almoſt like quick-ſilver. Now, tho' this dried mixture be, long after it is perfectly cold, not only ſoft, but ſo near to fluid, that I have caſt it into moulds, and made imboſs'd images of it; yet by laying it a few hours in the air, which ſeemed leſs cold than itſelf, it has acquired ſuch a hardneſs, that being thrown againſt the floor, it

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PHYSICS. it would rebound; and proved brittle, like over-harden'd ſteel: but in this example, the induration of the amalgam appears not to proceed from an innate and inward principle, but from the new texture, reſulting from the coalition of the mixed ingredients, which make up the amalgam; whoſe parts, being variouſly moved by means of the fire, and native propenſity of the mercurial corpuſcles to motion, were by degrees ſo diſpoſed, that as before, touching one another but looſely, it was eaſy to thruſt ſome of them towards the middle of the body, without ſtirring much of the maſs; by this change of texture, the particles are brought to touch one another more cloſely, and in greater portions of their ſurface, and to be ſo complicated among themſelves, that you cannot endeavour to thruſt one of them out of its place, but its motion ſhall be reſiſted by many others, whereto it is ſo faſten'd, that part of the maſs cannot be moved, without either moving the whole, or manifeſtly breaking it off from thence, and thereby deſtroying the continuity and union of the body. And that ſeveral of the ingredients did concur to conſtitute the ſoft maſs, which afterwards grew ſo hard, appears from hence, that the quick-ſilver was not ſo barely changed in texture, as that formerly ſaid to have been coagulated by the mere fume of lead, but concealed in itſelf a great number of metalline corpuſcles, beſides others; for we ſeparated from the amalgam, merely by the force of fire, a large quantity of true and perfect copper. That the ſalts alſo were both ingredients of the maſs, and might have ſome operation upon the other particles, ſeems probable: for having purpoſely expoſed ſome of this maſs for a while to a moiſt air, we found, that the formerly inviſible particles of ſalt, which had ſo inſinuated themſelves into the amalgam, that all the water, wherein it was waſhed, did not ſeparate them from it, had ſo wrought upon the external metalline particles, that they had, in many parts of the ſurface of the maſs, turned themſelves with it into a kind of verdigreaſe, which ſeemed almoſt to hide the ſurface of the concretion. And that in the more inward parts of a much harder body than our yielding amalgam, where cupreous particles abound, ſaline corpuſcles may have a great effect, appears from certain ſorts of minerals to be found in ſome parts of *England*, and elſewhere, under the form of ſtones, of which they make vitriol; for theſe abounding with vitriolate, that is, both ſaline and metalline particles, will, after they are taken out of the ground, and laid in the open air, by the working of the inward ſalt, ſome ſooner, and ſome later, ſwell and burſt aſunder: which could hardly happen, without a great change made in the internal diſpoſition of the parts of ſuch ſtony concretions. And having laid a mineral, of kin to theſe ſtones, for ſome time in the air, tho' but in a chamber, I found its ſurface powdered with little grains of vitriol, as both their colour and their taſte informed me. Now whether we ſuppoſe or no, that the fire put the parts of the amalgam into a laſting agitation; yet the maſs being almoſt fluid, after it was taken from the fire, its parts may, according to our notion of fluidity, be well ſuppoſed to have ſome kind of motion among themſelves; and it will not be denied, that the fire might concur, with other things, to make that motion convenient to cauſe the parts

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parts to faſten themſelves to one another; for that the motion, wherein a ſoft, and almoſt fluid body, is once put, may poſſibly tend to harden it, long after that motion ſeems to be extinct, appears probable, from what has been affirm'd to me by eminent and experienced maſons, that the beſt ſort of lime, made into mortar, will not have attain'd its utmoſt compactneſs, till within twenty-five, or thirty years, after it has been employed in building: and this is given me as one of the reaſons, why, in the demoliſhing of antient fabrics, it is ſometimes more eaſy to break the ſtone, than the mortar. And, laſtly, as to the texture reſulting from the blended ingredients of our amalgam; having changed the proportion of the quick-ſilver to the verdigreaſe, we found that it coagulated much more ſlowly, and when coagulated, was much ſofter, than when we uſed the quantities above ſet down. PHYSICS.

I ſhall add an inſtance of a natural induration, which, compared with our artificial one, may ſhew how nature and art have ſometimes reſembling operations in rendring bodies ſolid.

F. Pierre Pelleprat, who was lately ſent, with ſome other Jeſuits, to *South-America*, has this paſſage, in the ſhort relation he makes of the *American* continent. "It is," ſaith he, "worthy of obſervation, that near "the mouth of the great river of the *Amazons*, there is found a kind of "green clay, which is ſo ſoft, as long as it remains in the water, that one "may print on it all kinds of figures, and give it what ſhape one pleaſes; "but when it is expoſed to the air, it hardens to ſuch a degree, that dia-"monds are not much harder than the ſtones it affords." "I have," adds he, "ſeen hatchets made of this clay, which the ſavages employ'd to cut wood "with, when they had not the uſe of ours." In the laſt place, I ſhall give a remarkable experiment, to ſhew how much fluidity and firmneſs may depend upon the texture, motion, or reſt of the inſenſible parts of bodies. Make a ſolution of coral, with good ſpirit of vinegar, ſo ſtrong, that when filtred and cooled, it will, after ſome time, begin to have a ſediment; gently pour off the clear, when the experiment is to be made, and add thereto a convenient proportion of highly rectified ſpirit of wine; which if ſlowly and warily poured on, may be made to ſwim upon it as a diſtinct liquor; but if by a few ſhakes you mix them together, they will preſently concrete into a ſubſtance, of which, when the experiment is well made, not one drop will fall to the ground, upon turning the containing wide-mouth'd glaſs, and holding it upſide down. But if you add a convenient quantity of ſpirit of nitre to the mixture, and ſtir it briſkly therewith, the whole will in a few minutes be reduced to a tranſparent liquor*.

But

* Nothing can more conduce to explain the nature of fluidity and firmneſs, than the following paſſage of Sir *Iſaac Newton*. "The "parts of all homogeneal bodies, ſays he," "which

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Mr. Hobbs's *doctrine of fluidity and firmneſs examin'd.*

But I muſt not conclude this diſcourſe without obſerving, that when Mr. *Hobbs* diſputes againſt my opinion of fluidity, he very much miſtakes it; as may appear by this part of his phyſical dialogue. "They gene- "rally diſtinguiſh the nature of a fluid, from that which is not fluid, "by the greatneſs of the parts of which any body conſiſts: wherefore "they do not only look upon air, water, and liquors, but upon aſhes alſo, "and duſt, as fluid bodies; and deny not that fluids may be made "of ſolids; for they digeſt not the notion of infinite diviſibility: infinite "diviſion cannot be conceived, ſay they, but infinite diviſibility eaſily "may.

"which fully touch one another, ſtick to- "gether very ſtrongly. And for explain- "ing how this may be, ſome have in- "vented hooked atoms, which is begging "the queſtion; and others tell us, that "bodies are glew'd together by reſt, that "is, by an occult quality, or rather by no- "thing: and others, that they ſtick toge- "ther by conſpiring motions, that is, by "relative reſt among themſelves. I had ra- "ther infer from their coheſion, that their "particles attract one another by ſome force, "which, in immediate contact, is exceed- "ing ſtrong, at ſmall diſtances performs ma- "ny chymical operations, and reaches not "far from the particles with any ſenſible "effect. ——— All bodies ſeem to be com- "poſed of hard particles ——— even the "rays of light ſeemed to be hard bo- "dies ——— and therefore hardneſs may "be reckon'd the property of all uncom- "pounded matter ——— for all bodies, ſo "far as experience reaches, are either hard, "or may be harden'd ——— Now if com- "pound bodies are ſo very hard, as we find "ſome of them to be, and yet are very po- "rous, and conſiſt of parts which are only "laid together, the ſimple particles, which "are void of pores, and were never yet di- "vided, muſt be much harder. For ſuch "hard particles being heaped up together, "can ſcarce touch one another in more than "a few points, and therefore muſt be ſepara- "ble by much leſs force than is requiſite to "break a ſolid particle, where parts touch in "all the ſpace between them, without any "pores or interſtices to weaken their cohe- "ſion. And how ſuch very hard particles, "which are only laid together, and touch on- "ly in a few points, can ſtick together, and "that ſo firmly as they do, without the aſ- "ſiſtance of ſomething which cauſes them to "be attracted or preſſed towards one ano- "ther, is very difficult to conceive. ——— "Now the ſmalleſt particles of matter may "cohere by the ſtrongeſt attractions, and "compoſe bigger particles of weaker virtue; "and many of theſe may cohere, and com- "poſe bigger particles, whoſe virtue is ſtill "weaker, and ſo on for divers ſucceſſions, "till the progreſſion end in the biggeſt parti- "cles, on which the operations in chy- "miſtry, and the colours of natural bodies, "depend; and which, by cohering, com- "poſe bodies of a ſenſible magnitude." *Newton. Optic.* p. 364. ——— 370. From hence Dr. *Clarke*, treading in the ſteps of Sir *Iſaac*, thus argues. "The primitive and "moſt minute particles of matter cohere "among one another, not by reſt, but by "mutual attraction; and of theſe ſolid and "perfectly hard particles, 'tis plain, that all "bodies, both fluid and ſolid, are equally "compoſed. We are then to enquire what "muſt be the figure and compoſition of the "larger particles, in order to compoſe both "fluids and ſolids. Now, 1. when the par- "ticles of a body are ſo put together, that "they touch one another in large ſurfaces, "that body, the mutual attracton of its parts "being very ſtrong, will be exceeding hard. "And, 2. as thoſe parts afterwards only "touch, or are alſo interwoven among them- "ſelves, ſo the body will be more or leſs "brittle, and melt with a greater or leſs "heat; whence proceeds ice, wax, glaſs, "metals, bones, wood, &c. 3. The bodies, "whoſe particles touch in ſmaller ſurfaces, "and conſequently are leſs hard, may ſtill "be ſufficiently ſolid; whence gold is ſpeci- "fically heavier tho' leſs hard, than a dia- "mond. 4. That compact body, whoſe "particles, when preſs'd together, approach "nearer to, but yet do not ſlide over one "another, is hard and elaſtic, returning to "its figure with a force ariſing from the mutual

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" may. But I do not underſtand the diſtinction of fluids and not fluids, PHYSICS.
" which they take from magnitude; could I reliſh this, I muſt ſay, that
" the ruins of ſhatter'd ſtones, which lie in *Paul*'s church-yard, were
" fluid. But if thoſe ruins cannot be call'd fluid, becauſe the ſtones are
" too big, tell me the bigneſs that the parts of a ruin'd wall muſt have,
" to be call'd fluid? But let thoſe, who cannot underſtand infinite di-
" viſibility, tell me why I ſhould believe it more hard for almighty God
" to create a fluid body, leſs than any atom, that its parts might actu-
" ally flow, than to create the ocean. They, therefore, make me deſpair
" of receiving any benefit from them, by ſaying, that they think air, wa-
" ter, and other fluids, conſiſt of ſolids; as if a wall, that began to fall
" to ruin, were call'd by them a fluid body. If they may ſpeak ſo, every
" thing is fluid; for even marble itſelf may be broken into parts, leſs than
" any atom, imagin'd by *Epicurus*." But tho' I make the ſmallneſs of the parts, whereof a body conſiſts, one of the requiſites to its being fluid; yet I call the various agitation of thoſe particles the principal qualification, and the chief condition of a fluid body; Mr. *Hobbs*, therefore, much miſtakes, if he thinks that we always conſider aſhes and duſt as fluids, abſolutely ſpeaking: I always require, in the parts of a fluid, both minuteneſs, and ſuch a motion along each other, as makes them eaſily yield to the touch; which qualifications, how well they belong to the ruins of *Paul*'s, is not very difficult to determine. Mr. *Hobbs*

" mutual attraction of its parts. 5. If the " parts ſlide upon one another, the body is " malleable or ſoft. 6. If the particles touch " in very ſmall ſurfaces, the body is friable, " like ſnow, or eaſily ſeparable into its parts; " as two poliſh'd marbles adhering together " *in vacuo*, which may be disjoin'd by a " very ſmall force. 7. If they touch not " at all, or ſlip eaſily, and are of a fit ſize " to be agitated by heat, and the heat is great " enough to keep them in agitation, (tho' " perhaps much leſs is requiſite to keep wa- " ter from freezing) or only ſmall, voluble, " ſlippery, and of a figure and bulk diſpoſed " to motion, the body is fluid. Tho' the " particles, even of theſe moſt fluid bodies, " in ſome meaſure cohere together, as appears " from hence, that quick-ſilver will ſtand to " the height of ſixty or ſeventy inches in a " glaſs tube; that water will aſcend in ſmall, " open pipes *in vacuo*; and that drops of li- " quids preſerve their ſphericity *in vacuo*; " which is owing to the mutual attraction " of their parts. Now thoſe fluid bodies, " whoſe particles eaſily entangle with one an- " other, as thoſe of oil, or grow ſtiff with " cold, and become fixed, as it were, with " wedges, together, like thoſe of water, will " eaſily grow hard; but if their particles will " neither entangle, as thoſe of the air, nor " grow ſtiff with cold, as thoſe of quick-ſil- " ver, they will not cohere together. 8. If " the parts of a body are exceeding ſmall, " denſe, and ſpherical, that body may both " be fluid, and much heavier than others, " which are harder; their particles being leſs " ſolid, but touching one another in larger " ſurfaces. 9. If the particles of any body " may be agitated every way by a very briſk " motion, they will, whatever be their fi- " gure, conſtitute a fluid, as is the caſe of me- " tals in fuſion: but ſuch a body will pre- " ſently grow hard again, when that vio- " lent motion ceaſes. 10. Thoſe bodies, whoſe " particles are entangled with one another, " and touch in large furnaces, which are in " ſome meaſure, ſeparated, and will eaſily " ſlide over one another, prove either flexi- " ble, as leather; or very tenacious, as bird- " lime, pitch, *&c.*" See *Newton. Optic.* p. " 370. and *Clark. Annot. in Robault.* p. 109, " 110.

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PHYSICS. again makes uſe of the like example, and adds, that if we ſpeak at this rate, every thing is fluid; for, ſays he, marble may be reduced to parts ſmaller than the atoms of *Epicurus*. But I would gladly know by what art Mr. *Hobbs* can divide marble into leſſer particles, than ſuch as are naturally indiviſible; for ſuch *Epicurus* makes his atoms to be: nor do I ſee how, in caſe this could be done, it proves that every thing is fluid. For, I ſay, that the blocks of marble, before comminution, are not fluid, either according to him or me; nay, the greateſt comminution imaginable would not, according to my doctrine, make a lump of marble fluid, unleſs the heap, compoſed of the parts, how minute ſoever, were actually and variouſly ſet a moving amongſt themſelves. But he would, perhaps, have ſpoke more warily, if he had conſider'd the difference there is betwixt ſaying, that all things are fluid, and that there are many ſolid bodies, which, by comminution, motion, and other requiſite alterations, may be made parts of a fluid; as ſolid ice may be turned into fluid water; and quick-ſilver, precipitated *per ſe* into a red powder, be reduced to running mercury. As for what he ſays of an infinite diviſibility of body, it is ſcarce worth while to examine it; for I have ſhewn, that this diviſibility in no wiſe overthrows my doctrine of fluidity. Beſides, I do not well underſtand what he means, when he ſays, that an infinite diviſion is not conceivable, but an infinite diviſibility eaſily; for ſince he has recourſe, in this matter, to God's omnipotence, I ſee not why an infinite diviſion cannot be as well conceived, as an infinite diviſibility: ſure an omnipotent agent is able to do what is poſſible to be done, and why elſe ſhould a body be call'd infinitely diviſible? Beſides, it imports not to the controverſy about fluidity, to determine what the Almighty can do, but what he actually has done. And, laſtly, whereas my adverſary requires to have the magnitude defined, which a part of a falling wall ought to have, to deſerve the name of fluid; he ſhould firſt have clearly proved, that fluidity belongs to any one ſingle part of matter, how minute ſoever, and not rather to an aggregate of particles. And the corpuſcles that compoſe a fluid body, may be of ſeveral ſizes, as thoſe of water, oil, and quick-ſilver; provided they be minute enough to be put into the agitation requiſite to give the aggregate, they make up, the qualities neceſſary to denominate bodies fluid: and it is not requiſite for me to define preciſely the magnitudes of the parts of a fluid. Mr. *Hobbs* having afterwards aſk'd after the cauſes of hardneſs, is anſwer'd, that ſome aſſign three; to which he ſo far agrees as to ſay, "but the corpuſcles, ſuch as are ſuppoſed by *Lucretius*, and alſo by Mr. *Hobbs*, being hard before, might be eaſily compacted by any of theſe cauſes; ſo that it is not to be doubted, that the whole to be made of thoſe corpuſcles will be hard." But then he would have us aſſign the cauſe of that he calls *durum primum*. However, himſelf anſwers the objection he frames againſt my doctrine of hardneſs. He farther demands, "if hard bodies are made out of parts originally hard,

"why

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" why are not fluid bodies made of parts originally fluid? Could great PHYSICS.
" fluids, as the æther, be created, and not ſmall ones? He who firſt
" made a body hard or fluid, could, if he had pleaſed, have made it grea-
" ter or leſs than any other body. Now if a fluid body be made of parts
" not fluid, and hard bodies only from hard parts, doth it not follow,
" that neither fluid nor hard is made of original fluids?" But, firſt, he ſhould have told us what he means by his *prima fluida*, and how he knows there are any ſuch; for without this, 'twill be as hard for a conſidering man to acquieſce in his queſtion, as to anſwer it. For my part, I know no fluid body, upon account whereof, as an ingredient, all others are fluid. And, I think, 'twill be hard for Mr. *Hobbs* to ſhew, that water, quick-ſilver, rectified chymical oils, *&c.* conſiſt of ſuch *fluida prima*, as he teaches, whereto they owe all their fluidity And 'tis plain from experiments, and even the obvious changes of water and ice into one another, that 'tis the motion, reſt, and texture of the corpuſcles, which compoſe a body, that make it firm or fluid. As for what Mr. *Hobbs* demands, whether the ſmalleſt fluids imaginable could not as well have been created, as the æther; it proves nothing againſt me, the queſtion not being, what might have been made, but what is ſo. And he ſhould have anſwered the arguments I alledge, to render it improbable, that a fluid body is, as he would perſuade us, always diviſible into bodies equally fluid, as quantity into quantities. 'Tis true, he tells us, that " tho' many others do not, he underſtands by fluidity, that which is " made ſuch by nature, equally in every part of the fluid body, in ſuch " a manner as water ſeems fluid, and to divide itſelf into parts perpe-" tually fluid." But whether others will take this for a clear notion of fluidity, I think, may be doubted; and he ſhould not barely ſay, but prove, that the corpuſcles of water divide themſelves, ſo as he teaches; ſince we ſee, that they cannot penetrate glaſs, and are unable to be driven in at the pores of more open bodies, which other liquors eaſily enter. And, laſtly, to Mr. *Hobbs*'s queſtion, if fluids may be made of ſolids, *&c.* 'tis eaſy to give an anſwer, according to my doctrine; but till he has explain'd what he means by his *fluida prima*, and proved that there are ſuch, the queſtion needs no anſwer. Beſides, whatever he, thro' miſtake, ſtrives to infer, my doctrine is ſo far from aſſerting that there are many parts of matter, of which neither fluid nor hard bodies can be made, that I teach, there are multitudes of parts, which may, by being reduced to ſufficient ſmallneſs, and put into a convenient motion, or, by being brought to a mutual contact and reſt, be made to conſtitute either a fluid body, or a firm one. Mr. *Hobbs* thus delivers his own theory of fluidity and firmneſs: " The principles of flu-" idity and firmneſs, are nothing but reſt and motion. By reſt, I under-" ſtand that of two parts, one with another, when they touch, but not " preſs each other; for entire bodies of fluids may be in motion, and " their fluidity remain; and hard bodies be at reſt, tho' their parts are

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PHYSICS. " in motion." This, I doubt not, will, to moſt readers, ſeem a paradox; and as for his reaſoning, I ſhall readily allow him, that entire fluids may move, yet preſerve their fluidity; ſince that, I think, agrees at leaſt as well with my hypotheſis as his: but he adds, that hard bodies may reſt, and yet their parts be moved, which, in one caſe, may be conceived, and in another not. For the implicated parts of a firm body may be made to tremble or vibrate, as thoſe of a ſounding bell, or, as in a hedge, the branches and twigs may be ſhaken by the wind, whilſt the trees and buſhes themſelves continue rooted in the ground: but that in a *body*, the conſtituent corpuſcles ſhould all, or moſt of them, be moved quite out of their places, in reſpect of one another, as happens in fluids, and yet the body continue hard, is more requiſite than eaſy to be proved. But Mr. *Hobbs* contents himſelf to alledge, in favour of his ſtrange notion of fluidity and firmneſs, three particulars, which, I confeſs, afford me not the leaſt ſatisfaction. The firſt is drawn from what he formerly taught, of the ſwift motion of the air in our cylinder. He adds, " and " hence it is manifeſt, that there is a compreſſure in the air, thus moved " and ſhut up, as great as the force, by which it was driven in, could " make; and alſo, that from ſo great a compreſſure, ſome degree of con- " ſiſtence muſt ariſe, tho' leſs than that of water. Now if in all the ſame " particles of air, beſides the motion by which one preſſes another, there " was alſo the ſimple circular motion, and that vehement enough, it " would be almoſt impoſſible that any of them ſhould be moved from its " little circle; but that the other particles reſiſting the whole, would be " preſſed together, that is, become hard; for that is hard, of which no " part gives place, but upon the motion of the whole: hardneſs there- " fore may be made in a moſt fluid body, by this ſimple circular motion " of particles, which was before imparted to them by two contrary mo- " tions." But I do not ſee how the ſimple circular motion he talks of, ſhould give ſuch a hardneſs to the fluid air; nor is it manifeſt how the air, that perfectly fills the cylinder, can be by motion compreſs'd, eſpecially ſo far, as thereby to obtain a degree of conſiſtence, as he ſpeaks, leſs than the conſiſtence of water. For the cylinder being, according to him, perfectly full of air, how can the pumping make the cavity fuller than full, and conſequently compreſs the air to a conſiſtence, any thing near that of water, without penetration of dimenſions? But if there be not a various motion in the ſmall parts of water, whence is it that a lump of common ſalt, being thrown into a veſſel of that fluid, is there diſſolved into minute parts, many whereof are carried to the very top of the water, and ſo exquiſitely diffuſed and mixed with the whole, that each drop of it contains numbers of ſaline corpuſcles. And if motion be the cauſe rather of hardneſs than fluidity, how happens it, that in froſty weather, ice is by heat, which Mr. *Hobbs* will not deny to be motion, or an effect of it, turned from a hard to a fluid body? and that metals, whilſt they are either cold, or expoſed to a moderate heat, remain

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remain firm and conſiſtent bodies; but by a violent one, which manifeſtly gives their parts a various and vehement agitation, gain a fluidity, which, upon their removal from the fire, they quickly exchange for firmneſs? To conclude, I think I need not fear, that a doctrine, which I have, perhaps, with ſome care, endeavour'd to eſtabliſh, for the main, upon experiments, ſhould be overthrown by opinions, the grounds whereof are ſuch, as we have already ſeen; and in pleading for which, Mr. *Hobbs*, not only leaves almoſt all my arguments untouch'd, but never offers to explain, by his principles, any of thoſe numerous and important phenomena of fluidity and firmneſs, which I deliver.

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The MECHANICAL

ORIGIN and *PRODUCTION* OF VOLATILITY and FIXEDNESS.

SECT. I.

THE qualities which render a portion of matter volatile, are principally four; three whereof regard its ſingle corpuſcles, and the other the manner of their union into the body they compoſe. By corpuſcles or the minute parts of a body, I here mean not its elementary parts, as earth or water, ſalt or ſulphur; but ſuch, whether ſimple or compound, as have their component particles ſo firmly united, as not totally to be disjoined or diſſipated by that degree of fire wherein the matter they compoſe is ſaid to be volatile or fixed; ſo that they will, combined in their aggregate, either aſcend or remain unraiſed as one intire body. Thus in ſal-armoniac, whether it be a natural or a factitious thing, perfectly ſimilar, or compounded of different parts, I look upon an intire corpuſcle of it as a volatile portion matter; ſo I do upon a corpuſcle of ſulphur, tho' when 'tis kindled it yields much acid ſalt; which is not extricated by bare ſublimation. Thus alſo colcothar of vitriol falls under our conſideration as a fixed body, without inquiring what cupreous or other mineral, and not wholly fixed parts, may be united with the earthy ones; ſince the fires whereto we expoſe it, do not ſeparate them. Now in the firſt place, to make a volatile body, its parts ſhould be ſmall, becauſe ſuch are more eaſily put into motion by the action of the fire, or other agents; and conſequently more apt to be elevated by a force that tends upwards ſtronger than any other way. And if with this minuteneſs of parts, there be but a ſmall ſpecific gravity, their ſurface then being proportionably larger than in bigger particles, this will much more facilitate their elevation.

The qualities which render a body volatile, are, chiefly, four.

Smallneſs of parts.

'Tis next requiſite in the corpuſcles of volatile bodies, that they be not too ſolid or heavy; for otherwiſe, tho' their bulk be ſmall, they will uſually be hard to elevate, on account of their great ſpecific gravity, in reſpect of the air and the ſtrength of other agents. Thus tho' the parts of red

Rarity or lightneſs.

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PHYSICS. red lead be very ſmall, they cannot be eaſily blown about like duſt or meal.

Aptneſs to motion. A third qualification in a volatile body, is, that its parts be conveniently ſhaped for motion; for if they be branched, hooked, *&c.* they will be apt to be ſtopp'd or detain'd by other bodies, or to be entangled among themſelves, and conſequently very difficult to be carried upwards. And this may be one reaſon why water, tho' ſpecifically heavier than oil, is much more exhalable in vapour than it.

And a looſe texture, or weak cohesion. The laſt thing neceſſary in a volatile body, is, that its parts cohere looſely, or ſo as to diſpoſe them to be ſeparated by the fire, in the form of fume or vapour: otherwiſe one part will hinder the avolation of another, and their conjunction render them too heavy or unwieldy to riſe together, as intire parts. Thus a ſtrong wind, in the ſpring ſeaſon, is unable to carry off the lighteſt leaves of trees, becauſe they then ſtick faſt to the twigs; but in autumn, when that adheſion ceaſes, a gentle gale will ſerve to diſperſe them. But 'tis poſſible that the parts of a body may, by the figure and ſmoothneſs of their ſurfaces, be ſufficiently apt for motion, and yet be indiſpoſed to admit ſo much of it as would totally ſeparate and raiſe them into the air. As when ſalt-petre is, in a crucible, expoſed to the fire, tho' a very moderate degree of heat will bring the ſalt to fuſion, yet a greater degree of fire will not extricate ſo much as its ſpirit, and cauſe that to fly away *.

Five ways of introducing volatility into bodies. This doctrine may be both illuſtrated, and apply'd, by deducing from it the general ways of volatilizing bodies, or of introducing volatility into an aſſigned portion of matter. And theſe ways ſeem reducible to five, which I ſhall ſeverally mention, tho' both nature and art uſually employ two or more of them in conjunction. For which reaſon, I would not, when I ſpeak of one way, be underſtood to exclude the reſt, as if no other concurred in it.

The firſt way. The firſt of theſe ways of volatilizing a body, is by reducing it into minute parts, and *cæteris paribus*, the more minute the better. This appears from the vulgar practice of the chymiſts, who when they would ſublime or diſtil antimony, ſal-armoniac, ſea-ſalt, nitre, *&c.* beat them to powder to facilitate their receiving a farther comminution by the action of the fire. And in ſome bodies this comminution ought not to be made only at firſt, but to be continued afterwards. For chymiſts find by experience, that ſea-ſalt and nitre will very hardly afford their ſpirits in diſtillation, except they are mixed with powdered brick or bole, or ſome ſuch other addition; which uſually twice or thrice exceeds the weight of the ſalt itſelf. And altho' theſe additions, being themſelves fixed, ſeem unlikely to promote the volatilization of the bodies mixed with them; yet by preventing the ſmall grains of ſalt from melting together into one maſs, and conſequently keeping them in the ſtate of comminution, they

* Volatile bodies, according to Dr. *Friend*, in his chymical lectures, differ from fixed ones, in nothing but in having their particles more minute than they.

much

much conduce to drive up the ſpirits, or the finer parts of the ſalts. We may add, that in ſome caſes, the comminution is greatly to be promoted by mechanical means; and that, when the parts are brought to a great degree of ſmallneſs, they may be elevated much better than before. Thus if you mix filings of iron with ſal-armoniac, ſome few parts may be ſublimed; but if you diſſolve thoſe filings in good ſpirit of ſalt, and having coagulated the ſolution, calcine the greeniſh cryſtals, or *Vitriolum Martis*, that will be afforded, you may, with eaſe and expedition, obtain a *Crocus Martis* of very fine parts; ſo that I remember, when we exquiſitely mix'd two parts of this fixed powder, with three of ſal-armoniac, and gradually urged it with a competent fire; we elevated, at the firſt ſublimation, a great part of it; and adding a like, or ſomewhat leſs proportion of freſh ſal-armoniac to the *Caput mortuum*, we could raiſe ſo conſiderable a part of that alſo, and in it, of the *Crocus*, that if we had purſued the operation, we might, perhaps, have elevated the whole *Crocus*; which afforded a ſublimate of ſo very aſtringent a taſte, that it may make the trial of it in ſtanching of blood, ſtopping of fluxes, and other caſes, where potent aſtriction is deſired, worthy of a phyſician's notice. PHYSICS.

The ſecond means to volatilize bodies, is to rub, grind, or otherwiſe reduce their corpuſcles either to a ſmoothneſs, or ſome fit ſhape, that, ſo they may clear themſelves, or be diſintangled from each other. And to this inſtrument of volatilization, in concurrence with the firſt, may probably be referred the following phenomena: in the two former of which, there is employ'd no additional volatile ingredient; and in the fifth, a fixed body is diſpoſed to volatility by the operation of a liquor carefully abſtracted from it. (1.) If freſh urine be diſtilled, the phlegm will firſt aſcend, and the volatile ſalt not riſe, till that be almoſt totally driven away; and then it requires a conſiderable degree of fire to elevate it: but if you digeſt urine, in a well-cloſed glaſs veſſel, for ſeven or eight weeks, that gentle warmth will cauſe the ſmall parts ſo to rub againſt, or otherwiſe act upon, one another, that the finer ones of the ſalt will, perhaps, be made more ſlender and light; however, they will be made to extricate themſelves ſo far, as to become volatile, and aſcending in a very gentle heat, leave the greateſt part of the phlegm behind them. (2.) So if muſt, or the artificial wine of raiſins, be diſtilled before it hath fermented; the phlegm, but no inflammable ſpirit will aſcend. But when this liquor is reduced to wine by fermentation, which is accompanied with a great inteſtine commotion, ſome of the parts are qualify'd to riſe, by a very gentle heat, before the phlegm, and convene into that liquor we call ſpirit of wine. Nor is it only in the ſlighter inſtances afforded by animals, and vegetables, that volatility may be effected by theſe means: experience hath aſſured me, that it is poſſible by a long artificial digeſtion, wherein the parts have leiſure for frequent attritions, ſo to ſubtilize the corpuſcles, even of common ſalt, as to make them aſcend in a moderate fire of ſand, without the help of bole, oil of vitriol, or any volatilizing addition: and what is more conſiderable, the ſpirit would, in riſing, precede the phlegm, and *The ſecond way.*

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PHYSICS. leave the greateſt part thereof behind it. This inteſtine commotion of parts, capable of producing volatility in the more diſpoſed portions of a body, tho' it be much eaſier to be found in liquors, or in moiſt and ſoft bodies, yet I have ſometimes met with it in dry ones; and particularly, having cauſed muſtard-ſeed to be diſtilled *per ſe* in a retort, I had a great many grains of a clear, and figured volatile ſalt at the very firſt diſtillation. I leave it to farther enquiry, whether in a body ſo full of ſpirits as muſtard-ſeed, the action and re-action of the parts among themſelves, perhaps promoted by juſt degrees of fire, might not ſuffice to make in them a change equivalent, in order to volatilization, and the yielding a volatile ſalt, to that we have obſerved from fermentation and putrefaction in the juice of grapes, urine, *&c.* But as ſome trials made with other ſeeds, and among the reſt with aromatic ones, have afforded me no volatile ſalt; ſo the ſucceſs of others has ſometimes made me think, that ſome ſubjects of the vegetable kingdom, whence we commonly derive acid ſpirits, but no dry ſalt, may be diſtilled with ſo regular a heat, as to afford ſome volatile ſalt; and that more bodies would be found to do this, were they not too haſtily or violently urged by the fire. (3.) Tho' ſilver be one of the moſt fixed bodies we know, yet I am of opinion, that it is poſſible, chiefly by a change of texture, to render it volatile. An acquaintance of mine having hit upon a ſtrange menſtruum, tho' not corroſive, he abſtracted it from ſeveral metals, and brought me the remainders, with a deſire that I would endeavour to reduce thoſe of lead and ſilver to their priſtine form, which he had in vain attempted: but tho' I found the white calx of lead reducible, yet when I came to the calx of ſilver, I was unable to bring it into a body; and having at length melted ſome lead in a gentle fire, to try whether I could make it ſwallow up the calx, in order to a farther operation, I was ſurprized to find, that this mild heat made the calx of ſilver preſently fly away, and ſublime in the form of a *Farina volatilis*, which whitened the neighbouring part of the chimney and upper part of the crucible. (4.) From that which chymiſts themſelves tell us, we may draw a good argument, *ad hominem*, to prove, that volatility depends much upon the texture, and other mechanical affections of a body. For ſeveral of thoſe philoſophers, who write of the elixir, ſay, that when their philoſophic mercury or grand ſolvent, being ſealed up together with a third or fourth part of gold in a glaſs-egg, is kept in convenient degrees of fire, the whole matter, and conſequently the gold, will, by the mutual operation of the included ſubſtances, be ſo changed, as not only to circulate up and down in the glaſs, but in caſe the digeſtion or decoction ſhould be broken off at a certain inconvenient time, the gold would be quite ſpoiled; being, by the paſt and untimely-ended operation, made too volatile, to be reducible again into gold; whereas, if the decoction be duly continued to the end, not only the gold, but all the philoſophic mercury or menſtruum will be turned into a ſulphur or powder, of a wonderfully fixed nature. Now in this caſe, it is not by any thing ſuperadded, that the moſt fixed body of gold is made volatile; but the ſame maſſy matter, con-

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conſiſting of gold and philoſophic mercury, is, by the change of texture, occaſioned by the various degrees and operations of fire upon it, brought to be firſt volatile, and then extremely fixed. (5.) *Helmont*, amongſt other prodigious powers, which he aſcribes to the alkaheſt, affirms, that by abſtracting it often enough, it would ſo change all tangible bodies, and conſequently ſtones and metals, that they might be diſtilled over into liquors equal in weight to the reſpective bodies that afforded them, and having all the qualities of rain-water; and if ſo, they muſt be very volatile. And I ſee not how thoſe, who admit the truth of this ſtrange operation, can deny, that volatility depends upon the mechanical affections of matter; ſince the alkaheſt, at leaſt in our caſe, appears to work upon bodies mechanically. And it muſt be confeſſed, that the ſame material parts of a corporeal ſubſtance, which, when aſſociated and interwoven, after a determinate manner, conſtituted a ſolid and fixed body, as a flint, or a lump of gold; may by having their texture diſſolved, and by being freed from their former implications or coheſions, become the parts of a fluid body totally volatile.

The third way.

The third means of making a body volatile is, by aſſociating the particles to be raiſed, with ſuch as are more volatile than themſelves, and of a figure fit to be faſtened to them, or which are at leaſt apt, by being added to them, to make up therewith, corpuſcles more diſpoſed to volatility than they. This being the grand inſtrument of volatilization, I ſhall be the larger upon. But I muſt here obſerve, that 'tis poſſible the particles of an addition, tho' not more volatile than thoſe of the body it is mixed with, and perhaps, tho' not volatile at all, may yet conduce to volatilize the body wherewith it is mixed. For the particles of the thing added may be of ſuch figures, and ſo aſſociated with thoſe of the body to be elevated, as in this to enlarge its former pores, or produce new ones, by intercepting little cavities, between the particles of that body, and thoſe of the additional ingredient. For by theſe, and other ſuch ways of aſſociation, the corpuſcles, reſulting from the combination or coalition of two or more of ſuch different particles, may, without proving too big and unwieldy, be more conveniently ſhaped, or more light in proportion to their bulk, and ſo more eaſily buoyed up, and ſuſtained in the air, or otherwiſe more fitted for avolation, than when ſingle.

How the particles of an added ingredient may contribute to raiſe thoſe of another body.

The corpuſcles of the added ingredient may contribute to the elevation of a body chiefly by two things; firſt, the parts of the former may be much more diſpoſed for avolation, than is neceſſary to their own volatility. As when in the making of ſal-armoniac, the ſaline particles of urine, and of ſoot, are more fugitive than they need to be to raiſe themſelves; and thereby are advantaged to carry up with them the more ſluggiſh corpuſcles, whereof ſea-ſalt conſiſts. And next, they may be of figures ſo proper to faſten them to the body to be elevated, that the more fugitive will not be driven away, or diſjoined from the more fixed by ſuch a degree of heat, as is ſufficient to raiſe them both together. To which effect, the congruity or figuration, is as well required, as the lightneſs or volatility of the particles

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PHYSICS. cles of the thing added. And therefore ſome of the moſt fugitive bodies we know, as ſpirit of wine, camphire, *&c.* will not volatilize many ſubſtances, which might be elevated by far leſs fugitive things; becauſe the corpuſcles of ſpirit of wine ſtick not to thoſe of the body they are mixed with, but eaſily flying up themſelves, leave thoſe behind them, which they rather barely touch'd, than firmly adhered to; whereas, far leſs ſubtile liquors, if they be endowed with figures, which fit them for a competently firm coheſion with the body they are mixed with, will be able to volatilize it. And of this I ſhall give ſome inſtances in bodies very ponderous, or very fixed, or both. To begin with colcothar; which being a vitriolic calx, made by a laſting and vehement fire, is, conſequently, capable of reſiſting ſuch an one; yet this, when exquiſitely ground with an equal weight of ſal-armoniac, a ſalt but moderately volatile, will be in great part ſublimed into thoſe yellow flowers we call *Ens primum Veneris*; in which, that many vitriolic corpuſcles of the colcothar are really elevated, will eaſily appear by putting a grain or two of that reddiſh ſubſtance into a ſtrong infuſion of galls, which thereby immediately acquires an inky colour. Steel alſo, (which muſt have endured extraordinary violences of the fire,) being reduced to filings, and diligently ground with about an equal weight of ſal-armoniac, will, if degrees of fire be ſkilfully adminiſtred, without any previous calcination or reduction into a crocus, ſuffer ſo much of the metal to be carried up, as to give the ſal-armoniac a notable colour, and a chalybeate taſt. And here it will be proper to obſerve, for the ſake of practical chymiſts, that the proportion of the volatile addition is to be regarded. Several bodies thought unfit for ſublimation, or incapable of having any conſiderable portion of them elevated, may be plentifully ſublimed, if a greater proportion of the addition, than uſual, is ſkilfully employ'd. Thus in the inſtance of filings of ſteel, if inſtead of an equal weight of ſal-armoniac, the treble weight be taken, and the operation duly managed, a far greater quantity of the matter may be raiſed, eſpecially if freſh ſal-armoniac be careſully ground with the *Caput mortuum*. And ſal-armoniac may perhaps be compounded with ſuch other bodies, heavier than itſelf, as may qualify it, when it is thus clogged, to elevate ſome fit ſubſtances, better than it would of itſelf alone. I ſhall add, that if beſides the plenty of the foreign ingredient, there be a ſufficient fitneſs of its particles, to lay hold on thoſe of the body to be wrought on, ponderous mineral bodies may be employ'd to volatilize other heavy bodies. I am apt to think, that almoſt all metals may, by large additions and frequent cohobations, be brought to paſs through the neck of the retort, in diſtillation; and perhaps, if they be melted, not with equal parts, but with many more, of regulus of antimony, and the proceſs be managed as the hints now given direct, what I have ſaid may not prove unſerviceable. Many attempts have been, and are ſtill fruitleſsly made by chymiſts to elevate ſalt of tartar with additions. Now I ſhall only obſerve, that as frequent experience ſhews, if ſal-armoniac be abſtracted from ſalt of tartar, not only the ſalt of tartar is left at the bottom, but a large part of the

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the ſal-armoniac with it; I ſuſpected the cauſe might be, that ſal-armo- PHYSICS.
niac, by the operation of the alkali of tartar, is reduced into ſea-ſalt, and an urinous one, having been at firſt compoſed of thoſe different ingredients; and by this means the volatile ſalt being looſened from the the reſt, flies eaſily away, without ſtaying long enough to take up any other ſalt with it: and therefore, if this analyſis of the ſal-armoniac could be prevented, it ſeem'd not impoſſible, that ſome part of the ſalt of tartar, as well as of colcothar and ſteel, might be carried up by it. And accordingly, having cauſed the ingredients to be exceedingly well dried, and both nimbly and carefully mixed, and ſpeedily expoſed to the fire; I have ſometimes had a portion of ſalt of tartar, carried up with the ſal-armoniac; but this happened ſo very rarely, that I ſuſpected there muſt be a peculiar fitneſs for this work in ſome parcels of ſal-armoniac, which are ſcarce, but by the effect, to be diſcerned from others. This, however, argues the poſſibility of the thing, and may ſerve to ſhew the volatilizing efficacy of ſal-armoniac; which is a compound that I recommend, as one of the moſt uſeful productions of vulgar chymiſtry.

Salt of tartar volatilized.

But, by the way, there ſeems to be a great deal of difference between making a volatile ſalt of tartar, and the making ſalt of tartar volatile. It is very poſſible, that a man may from tartar obtain a volatile ſalt, and yet not be able to volatilize that tartareous ſalt, which has once, by incineration, been brought to a fixed alkali. There is a way, whereby ſome chymiſts obtain a volatile ſalt from a mixture of antimony, nitre, and crude tartar, which, probably, comes from the latter; but experience hath aſſured me, that by a diſtillation ſlowly made, without any addition, very clean tartar, or at leaſt, the cryſtals of tartar, may, in conveniently ſhaped veſſels, be brought to afford a ſubſtance, which, in rectification, will aſcend to the upper part of the veſſel, in the form of a volatile ſalt; as if it were of urine, or of hart's-horn: tho' this operation requires a dextrous and a patient diſtiller. But to render a fixed alkali of tartar volatile, I take to be another, and a far more difficult work; for the common proceſſes of performing it, promiſe much more than they can make good. I have convinced ſome of the more ingenuous chymiſts, that the ſublimed ſalt was not indeed the alkali of tartar, but ſomewhat produced by the operation, or rather extricated out of the addition. Yet I would not be thought to affirm, that it is impoſſible to elevate the fixed ſalt of tartar. For ſometimes I have been able to do it, even at the firſt diſtillation, by an artificial addition, perhaps more fixed than itſelf; but tho' the operation was very grateful to me, as it ſhew'd the poſſibility of the thing, yet the ſmall quantity of the ſalt ſublimed, and other circumſtances, kept me from much valuing it upon any other account. And there are other ways, whereby experience has aſſured me, ſalt of tartar may be raiſed. And if one of them were not ſo uncertain, that I can never promiſe before-hand that it will ſucceed; and the other ſo laborious, difficult and coſtly, that few would attempt, or be able to practiſe it, I ſhould think them very valuable; ſince by the former, moſt part of the ſalt of

PHYSICS. of tartar was quickly brought over in the form of a liquor, of a ſcent intolerably piercing; and by the latter, ſome ſalt of tartar of my own, being put into a retort, and urged but with ſuch a fire, as could be given *in* a portable ſand-furnace, there remained not at the bottom near one half of the firſt weight; the addition having carried up the reſt, partly in the form of a liquor, but chiefly in that of a white ſublimate, which was neither ill-ſcented, corroſive in taſte, nor alkalizate, but very mild, and ſomewhat ſweetiſh. And I doubt not that by other ways, the fixed alkali of tartar may be elevated, eſpecially if, before it is expoſed *to the* laſt operation of the fire, it be dextrouſly freed from the moſt of thoſe earthy and viſcous parts, which, I think, may be juſtly ſuſpected to clog and bind ſuch as are truly ſaline. I ſhall only farther intimate, that even the ſpurious *Sal Tartari*, volatilized with ſpirit of vinegar, may, if well prepared, make amends for its empyreumatical ſmell and taſt; and in ſeveral caſes, be of no deſpicable uſe, both as a medicine and a menſtruum.

Repeated ſublimations do not always increaſe the quantity of the ſublimate.

There is a phenomenon, which may much ſurprize, and ſometimes diſappoint thoſe who deal in ſublimations, unleſs they are fore-warned of it. For tho' it be taken for granted, that by carefully mixing what is ſublimed, with what remains, and re-ſubliming the mixture; a greater quantity of the body to be ſublimed may be elevated the ſecond time, than was the firſt; and the third time than the ſecond, and ſo on; yet I have not found this rule always to hold true; but in ſome bodies, as particularly in ſome kinds of dulcified colcothar, the ſal-armoniac would, at the firſt ſublimation, carry up more of the fixed powder, than at the ſecond or third. So that I was, by ſeveral trials, perſuaded, when I found a very well and highly coloured powder elevated, to lay it by for uſe, and thereby ſave myſelf the labour of a proſecution, which would not only have proved uſeleſs, but prejudicial. And by often returning ſal-armoniac upon crude antimony, though the ſublimate, obtained by the firſt operation, was, much of it, variouſly coloured; yet, afterwards, the ſalt aſcended, from time to time, gradually paler, leaving the antimony behind it: which way of making minerals more fixed and fuſible, I conceive may be of great uſe in ſome medicinal preparations. But I chiefly intend here to conſider, whether the preſent phenomenon may be aſcribed to the repeated action of the fire, grinding together the bodies to be raiſed; whence either the corpuſcles of the ſal-armoniac, or of the other body, may have thoſe little hooked, or equivalent particles, whereby they take hold of one another, broken or worn off; and whether the indiſpoſition of the colcotharine or antimonial parts to aſcend, may not in ſome caſes be promoted by their having, from frequent attritions, ſo ſmoothed their ſurfaces, that ſeveral of them may cloſely adhere like pieces of poliſhed glaſs, and ſo make up cluſters too unwieldly to be raiſed, as the ſingle corpuſcles they conſiſt of were; which change may diſpoſe them to be, at once, leſs volatile, and more fuſible. And here it may be

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ſerviceable to obſerve, that ſublimations are applicable to make very fine comminutions of ſeveral bodies. That thoſe which are elevated are reduced to a great fineneſs of parts, is obvious in many examples, whence it has been anciently ſaid, that ſublimations are the chymiſt's peſtles; ſince they really reſolve the elevated bodies, into exceeding fine flower, and much finer than the peſtle and mortar can reduce them. But what I intend is, that ſometimes, even bodies ſo fixed, as not at all to aſcend in ſublimation, may yet be reduced, by that operation, into powders extremely fine. For tho' chymiſts complain much of the difficulty of making a good calx of gold, and of the imperfection of the few ordinary proceſſes, preſcribed to make it; yet, we have found, upon trial, that by exactly grinding a thick amalgam of gold and mercury, with a competent weight of finely powdered ſulphur, we may, upon putting the mixture to ſublime in a conveniently-ſhaped glaſs, by degrees of fire, obtain a cinnabar, which will leave behind it a finer calx of gold, than can be had from ſome far more difficult proceſſes. PHYSICS.

The fourth way of introducing volatility into bodies.

To proceed to our fourth way. Volatility depends ſo much upon the contexture of the corpuſcles, which are to be raiſed together, that even very ponderous bodies may ſerve for volatilizing ingredients, if they be diſpoſed to faſten themſelves ſufficiently to the bodies they are to carry up along with them. For quick-ſilver, being united by amalgamation with a ſmall proportion of lead, will, by a moderate fire, and in cloſe veſſels, be made to carry over with it ſome of the lead; as we have found by the increaſed weight of the quick-ſilver, that paſſed into the receiver: which, by the way, may make us cautious, how we conclude quick-ſilver to be pure, merely from its having been diſtilled. There remains but one body more heavy than thoſe we have mentioned, and that is gold; which being of a ſurprizing fixity, I do not wonder that the wary naturaliſts, and the more ſevere among the chymiſts, ſhould think it incapable of being volatilized. Yet if we conſider, how very minute parts gold may be rationally ſuppoſed to conſiſt of, and to be diviſible into; methinks it ſhould not ſeem impoſſible, that if we could light on volatile ſalts, of figures fit to ſtick faſt to the corpuſcles of the gold, they would carry up with them particles, whoſe ſolidity can ſcarce be more extraordinary than their minuteneſs: and in effect, we have made more than one menſtruum, with which ſome particles of gold may be carried up. But when I employed my *Menſtruum peracutum*, (which conſiſts of ſpirit of nitre, ſeveral times drawn from butter of antimony,) I was able, without a very violent fire, and in a few hours, to elevate ſo much crude gold, as, in the neck of the retort, afforded me a conſiderable quantity of ſublimate; which I have had, red as blood: and that it conſiſted partly of gold, manifeſtly appeared by this, that I was able, with eaſe, to reduce that metal out of it.

But in reckoning up the inſtruments of volatilization, we muſt not omit to mention the air; which I have often obſerved to facilitate the elevation

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PHYSICS. tion of ſome bodies, even in cloſe veſſels. And, though to fill theſe high, be judged, by many, a ſhort method, becauſe the ſteams have then a leſs way to aſcend; yet frequent experience has informed me, that, at leaſt in ſome caſes, they take wrong meaſures, and that a large proportion of air, purpoſely left in the veſſels, may more than make amends for the greater ſpace, that is to be aſcended by the vapours or exhalations of the matter to be diſtilled or ſublimed. And if, in cloſe veſſels, the preſence of the air may promote the aſcent of bodies; it may well be expected, that the elevation of ſeveral of them may be furthered by being attempted in open veſſels, to which the air hath free acceſs. And if we may credit the probable relations of ſome chymiſts, the air much contributes to the volatilization of particular bodies, which are barely expoſed to it. But the account on which the air, by its bare preſence, or peculiar operations conduceth to the volatilization of ſome bodies, is a thing very difficult to be determined, without a due regard to gravity, levity, and the conſtitution of the corpuſcles that compoſe the air, which I take to be very numerous, and various.

I have hitherto generally conſidered the ſmall portions of matter, to be elevated in volatilization, as intire corpuſcles; but there may alſo happen caſes, wherein a kind of improper volatilization is effected, by making uſe of ſuch additions, as break off, or otherwiſe divide the particles of the corpuſcles to be elevated; and, by adhering to, and ſo clogging one of the particles, to which it proves more fit, enable the other, which is now brought to be more light, or diſengaged, to aſcend. Thus, when ſal-armoniac is well ground with *Lapis Calaminaris*, or with ſome fixed alkali, and committed to diſtillation; the ſea-ſalt, which enters the compoſition of the ſal-armoniac, being detained by the ſtone, or the alkali, there is a divorce made between the common ſalt, and the urinous, and fuliginous ſalts, that were incorporated with it; and being now diſengaged from it, are eaſily elevated. And I have obſerved, in human urine, a kind of native ſal-armoniac, much leſs volatile than that ſublimed from human blood, harts-horn, *&c*: and therefore, ſuppoſing a ſeparation of parts may be made by an alkali, as well in this ſalt, as in the common factitious ſal-armoniac, I put to freſh urine a convenient proportion of the ſalt of pot-aſhes; and diſtilling the liquor, it yielded a ſpirit more volatile than the phlegm; and of a very piercing taſt: which way of obtaining a ſpirit, without any violence of fire, and without either previouſly abſtracting the phlegm, or waiting for the fermentation of ſtale urine, I taught ſome chymiſts, becauſe of the uſefulneſs of ſpirit of urine, which being obtained by this innocent way, might, probably, be employed, with much leſs ſuſpicion of corroſiveneſs, than if quick-lime had been uſed in the operation. And in making ſpirit of nitre, by mixing ſalt-petre with oil of vitriol, and diſtilling them together; the oil ſo divides or breaks the corpuſcles of the nitre, that the new-diſpoſed particles of that ſalt, which amount to a great portion of the whole, will be made eaſily to aſcend, even with

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a moderate ſand-heat, and ſometimes without any fire at all, in the form of a *ſpirit* exceeding ſubtile, and volatile. PHYSICS.

The fifth way of rendering bodies volatile.

The laſt means of volatilizing bodies, is, the operation of the fire, or ſome other actual heat. But of this, which is ſo obvious, it were needleſs to diſcourſe. I ſhall only intimate, that there may be bodies, which, in ſuch degrees of fire, as are uſually given in the vulgar chymical operations, will not riſe, may yet be forced up by ſuch violent and laſting fires, as are employed by the melters of ores, and founders of guns, and ſometimes by glaſs-makers. And indeed, tho' I here conſider volatility and fixedneſs in the popular ſenſe of thoſe terms; yet if we would view the matter more ſtrictly, I preſume, we ſhould find, that they are but relative qualities, and to be eſtimated, eſpecially the former, by the degree of fire, to which the body, whereto we aſcribe one or other of theſe qualities, is expoſed; and therefore it is much more difficult, than men are aware of, to determine accurately, when a body ought to be accounted volatile, and when not; ſince there is no determinate degree of heat agreed on, nor indeed eaſy to be deviſed, for a ſtandard, whereby to meaſure volatility and fixedneſs: and it is obvious that a body, which remains fixed in one degree of fire, may be forced up by another. Beſides, a body may paſs for abſolutely fixed, among the generality of chymiſts, and yet be unable to endure the fires of founders and glaſs-makers. Having not obſerved, that chymiſts had examined the fixity of other bodies than metalline ones by the cupel, I put dry ſalt of tartar upon it; and found, that in no long time it manifeſtly waſted in ſo vehement a heat, whilſt alſo the air came freely at it. And having well mixed one ounce of good ſalt of tartar with treble its weight of tobacco-pipe clay, we kept them but for two or three hours in a ſtrong fire; yet the crucible being purpoſely left uncovered, we found the ſalt ſo waſted, that the remaining mixture afforded us not near a quarter of an ounce of ſalt. And indeed I ſcarce doubt, that in ſtrictneſs, ſeveral of thoſe bodies, which paſs for abſolutely fixed, are but comparatively and relatively ſo; that is, in regard to ſuch degrees of fire, as they are uſually expoſed to in the diſtillations, ſublimations, *&c.* of chymiſts. And, perhaps, even the fires of founders and glaſs-makers, are not the moſt intenſe, that might, poſſibly, be made in a ſhort time, provided only ſmall portions of matter were to be wrought on by them. In effect, I know very few bodies, beſides gold, that will perſevere totally fixed in the moſt vehement degrees of fire wherewith I have made experiments. And though tin is in our chymical reverberatories uſually reduced but into a calx, which is reputed very fixed; yet in thoſe intenſe fires, which an acquaintance of mine uſes in his tin-works, quantities of tin are often carried up to a conſiderable height, in the form of a whitiſh powder, which being in large maſſes forced off from the places, whereto it had faſtened it ſelf, yields, by a ſkilful reduction, great quantities of good malleable metal, that ſeems to me rather more fine than ordinary tin.

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SECT. II.

Qualifications for fixedneſs in bodies.

FIxedneſs being the oppoſite quality to volatility, what we have diſcourſed of the former, will help to clear up the nature of the latter.

The qualifications moſt conducive to render a portion of matter fixed, ſeem to be, 1. The groſſneſs or bulk of its component parts. 2. The ponderoſity or ſolidity of them. 3. And laſtly, an indiſpoſition of their corpuſcles for avolation, ariſing from the texture of the body. And from theſe cauſes or requiſites of firmneſs, may be deduced the following means of giving or adding fixation to a body, which was before either volatile or leſs fixed: and they are reducible to two general heads; the action of the fire, as the parts of the body expoſed to it, are thereby made to operate variouſly on one another; and to the aſſociation of the particles of a volatile body, with thoſe of ſome proper additional one. But theſe two inſtruments of fixation being general, I ſhall propoſe four or five more particular ones.

The firſt way of producing fixedneſs, by means of fire, or the addition of other matter.

And firſt, in ſome caſes, it may conduce to fixation, that, either by an addition, or by the operation of the fire, the parts of a body be brought to touch each other in large portions of their ſurfaces. For, that from this contact, there muſt follow ſuch a mutual coheſion, as will at leaſt indiſpoſe the touching corpuſcles to ſuffer a total divulſion, may appear from the coheſion of flat pieces of marble and glaſs, and from ſome other phenomena belonging to the hiſtory of firmneſs; whence we may properly borrow ſome inſtances, for illuſtration, in the doctrine of fixedneſs; ſince, uſually, the ſame things, which make a body firm, give it a degree of fixedneſs, in keeping it from being diſſipated by the uſual degrees of heat and agitation of the air. Beſides this, 'tis not impoſſible, that the bare operation of the fire may, in ſome caſes, procure a coheſion among the particles, as well as disjoin them in others, and thereby make them more volatile. For, as in ſome bodies, the action of the fire may rub off the little hooks, that entangle them, and make it more eaſy for the corpuſcles to be diſengaged, and fly upwards; in others the agitation of the fire may grind their ſurfaces ſo ſmooth, as to admit of a firm contact and coheſion. Thus in grinding glaſſes for teleſcopes and microſcopes, the artificer, by long rubbing a piece of glaſs againſt a metalline diſh, brings the two bodies to touch one another, in ſo many parts of their ſurfaces, that they will moſt firmly adhere to one another. And if two groſſer corpuſcles, or a greater number of ſmaller be thus brought to ſtick together, their aggregate will prove too heavy to fly away. And to ſhew that the fire may effect a levigation in the ſurfaces of ſome corpuſcles, I have cauſed *Minium*, and other calces to be melted in a vehement fire, whereby that which was before a dull and incoherent powder, was reduced into much groſſer corpuſcles; multitudes of

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of their grains appearing ſmooth, glittering, and almoſt ſpecular, like thoſe of fine litharge of gold: and the maſſes which theſe grains compoſed, were uſually ſolid, and of difficult fuſion. When we make glaſs of lead *per ſe*, it is plain, that the particles of the lead are reduced to a great ſmoothneſs; ſince whereſoever you break the glaſs, the ſurfaces produced will not be jagged, but ſmooth, and conſiderably ſpecular. It ſeems, alſo, poſſible, that even when the fire doth not make any great attrition of the particles of the body to be fixed, it may yet occaſion their ſticking together; becauſe it may at length, after multitudes of revolutions, and occurſions, bring thoſe of their ſurfaces to join, which by reaſon of their breadth, ſmoothneſs, or congruity of figure, are fit for mutual coheſion; and when once they come to ſtick, there is no neceſſity, that the ſame cauſes, which were able to make them paſs by one another, when their contact was only in an inconſiderable part of their ſurfaces, ſhould have the ſame effect now, when their contact is full; though perhaps, if the degree of fire was much increaſed, a more vehement agitation would ſurmount this coheſion, and diſſipate, again, theſe cluſters of coaleſcent particles. PHYSICS.

Theſe conjectures will appear the leſs extravagant, if we conſider what happens in quick-ſilver made precipitate *per ſe*. For here, running mercury is expoſed to a moderate fire for a conſiderable time, whereby the parts of the mercury are variouſly agitated, and many of them made to aſcend; till convening into drops on the ſides of the glaſs, their weight carries them down again; but at length after many mutual occurſions, and perhaps attritions, ſome of the parts begin to ſtick together in the form of a red powder, and then gradually, more and more, and mercurial particles are there faſtened together, till at length, all, or by much the greater part of the mercury is reduced into the like precipitate; which, by this coheſion of parts, being grown more fixed, will not, with the ſame degree of heat, be made to riſe and circulate, as the mercury would before; yet I have found by trial, that with a greater and a competent degree of heat, this precipitate *per ſe* would, without the help of any volatilizing ingredient, be eaſily reduced into running mercury again. Chymiſts, who agree in ſuppoſing this precipitate made without any addition, will ſcarce be able to give a more probable account of the conſiſtence obtained by the mercury; wherein, ſince no body is added to it, there appears to be wrought none but a mechanical change. And though I have ſuſpected, that in philoſophical ſtrictneſs, this precipitate may not be made *per ſe*, but that ſome penetrating particles of the fire, eſpecially ſaline ones, may have aſſociated themſelves with the mercurial corpuſcles; yet, even upon this ſuppoſition, it may be ſaid, that theſe particles contribute to the effect, but by facilitating the mutual coheſion of corpuſcles, that would not otherwiſe ſtick to one another. And, as for the generality of chymiſts, who aſſert the tranſmutation of all metals into gold, by the philoſopher's ſtone, they muſt grant it probable, that a new and fit contexture of the parts of a volatile body, may greatly

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PHYSICS. ly contribute to render it highly fixed. For, it is averr'd by *Helmont*, who pretended not to the elixir, that a grain of a powder, which was given him, tranſmuted a pound of running mercury; where the proportion of the elixir to the mercury was ſo inconſiderable, that it cannot reaſonably be ſuppoſed, that every corpuſcle of the quick-ſilver, which before was volatile, became extremely fixed, merely by its coalition with a particle of the powder; ſince, to make one grain ſuffice for this coalition, the parts it muſt be divided into, will be ſcarce conceivably minute; and therefore each ſingle part was not likely to be fixed *it ſelf*; or at leaſt it was more likely to be carried up by the mercury, than to keep that from flying away: whereas, if we ſuppoſe the elixir to have made ſuch a commotion among the corpuſcles of the mercury, as to bring them to ſtick to one another, it is agreeable to the mechanical doctrine of fixedneſs, that the mercury ſhould endure the fire as well as gold, on account of its new texture, which, ſuppoſing the ſtory true, appears to have been introduced, by the new colour, ſpecific gravity, indiſſolubility in *Aqua fortis*, and other qualities, wherein gold differs from mercury; but eſpecially malleableneſs, which uſually requires, that the parts, from the union whereof it reſults, be either hooked, branched, or otherwiſe adapted and fitted to make them take faſt hold of, or ſtick cloſe to one another. And ſince in the whole maſs of the factitious gold, all, except one grain, muſt be materially the ſame body, which, before the projection, was quick-ſilver; we ſee, how great a proportion of volatile matter may, by an inconſiderable quantity of addition, acquire ſuch a new diſpoſition of its parts, as to become moſt fixed. However, this inſtance agrees much better with the mechanical doctrine, than with this vulgar opinion of the chymiſts, that, if in a mixture, the volatile part much exceeds the fixed, it will carry up this with it, and on the contrary. But though the rule holds in many caſes, where there is no peculiar indiſpoſition to the effect that is aimed at; yet, if the mechanical affections of the bodies be ill ſuited to ſuch a purpoſe, our philoſophical experiment manifeſtly proves, that the rule is falſe; ſince ſo great a multitude of grains of mercury, inſtead of carrying up with them one grain of the elixir, are detained by it in the ſtrongeſt fire.

A ſecond way by altering or expelling the volatile particles.

The ſecond way of producing fixedneſs, is by expelling, breaking, or otherwiſe diſabling thoſe volatile corpuſcles, which are too indiſpoſed to be fixed themſelves; or are fitted to carry up with them ſuch particles as would not, without their help, aſcend. That the expulſion of ſuch parts is a proper means to make the aggregate of thoſe, which remain, more fixed, will not want proof, if we conſider the inſtance of it in ſoot; where, though many active parts were, by the violence of the fire, and the current of the air, carried up together by the more volatile parts; yet when the ſoot is well diſtill'd, in a retort, a competent time being allow'd for the extrication and avolation of the other parts, there will, at the bottom, remain a ſubſtance, which will not now fly away, as before. And here let me obſerve, that the receſs of the fugitive corpuſcles may contribute to the fixation of

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of a body, not barely becauſe the remaining matter is freed from ſo many volatilizing parts, but becauſe upon their abſence, the pores or intervals, they leave behind, are filled up with more ſolid or heavy matter; and the body becomes more homogeneous, cloſe and compact. And, beſides the expulſion of unfit corpuſcles, which may be otherwiſe diſabled from hindering the fixation of the maſs they belong to; it ſeems very poſſible, that in ſome caſes they may, by the action of the fire, be ſo broken, as with their fragments to fill up the pores or intervals of the body they appertain'd to; or may make ſuch coalitions with the particles of a convenient addition, as to be no impediment to the fixity of the whole maſs, though they remain in it.

A third way, by ſecuring reſt.

The third means of fixing bodies, is, by preſerving that reſt among the parts, whoſe contrary is neceſſary to their volatilization. And this may be done by preventing or checking that heat, or other motion, which external agents ſtrive to introduce into the propoſed body. But this tending rather to hinder the actual avolation of a portion of matter, or, at moſt, to procure a temporary abatement of its volatility, than to give it a ſtable fixity, I ſhall not any longer inſiſt on it.

A fourth way, by complicating the parts.

The fourth way of producing fixedneſs in a body, is, by putting to it ſuch an appropriated addition, whether fixed or volatile, that the corpuſcles of the body may be put among themſelves, or with thoſe of the added ingredient into a complicated ſtate. This being the uſual and principal way of producing fixity, we ſhall dwell the longer upon it, and give inſtances of ſeveral degrees of fixation. And firſt we find, that a fixed addition may eaſily give a degree of fixity to a very volatile body. Thus ſpirit of nitre, which will, of it ſelf, eaſily fly away in the air, having its ſaline particles aſſociated with thoſe of fixed nitre, or ſalt of tartar, will, with the alkali, compoſe a ſalt of a nitrous nature, capable of being melted in a crucible, without loſs of its ſpirit. And I have found that the ſpirit of nitre, which abounds in *Aqua fortis*, being coagulated with the ſilver, they corrode, and the cryſtals produced by their coalition, being put into a retort, may be kept for ſome time in fuſion, before the metal will let go the nitrous ſpirit. When we poured oil of vitriol upon the calx of vitriol, though many particles were driven away by the excited heat; yet the ſaline parts, which combined with the fixed ones of the colcothar, ſtuck faſt to them. And if oil of vitriol be, in a due proportion, dropp'd upon ſalt of tartar, there reſults a *Tartarum Vitriolatum*, wherein the acid and alkaline parts cohere ſo ſtrongly, that it is not an ordinary degree of fire that can disjoin them; whence ſeveral chymiſts have thought this compound ſalt to be indeſtructible. But a leſs heavy liquor than the oil of vitriol, may, by an alkali, be more ſtrongly detained, than that oil it ſelf; for experience has aſſured me, that ſpirit of ſalt, being dropp'd, to ſatiety, upon a fixed alkali, there will be made ſo ſtrict an union, that a ſtrong and laſting fire cannot ſo much as melt the mixture.

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PHYSICS. But it is not the bare mixture of volatile particles with fixed ones, that will ſuffice to elevate the latter. For unleſs the figures of the latter be correſpondent, and fitted to faſten to the other, the volatile parts will fly away in the heat, and leave the reſt as fixed as before. Thus, when ſand or aſhes are wetted with water, they quickly part with that water, without parting with any degree of their fixity. On the other ſide, it is not always neceſſary, that the body, which is fitted to deſtroy, or greatly abate the volatility of another, ſhould be it ſelf fixed. For, if there be a ſkilful coaptation of the figures of the particles of both the bodies, theſe particles may take ſuch hold of one another, as to compoſe corpuſcles, which will neither, by reaſon of their ſtrict union, be divided by heat, nor by reaſon of their reſulting groſſneſs be elevated even by a ſtrong fire, or at leaſt by ſuch a degree of heat, as would have ſufficed to raiſe more indiſpoſed bodies, than either of the ſeparate ingredients. In preparing the *Bezoardicum Minerale*; though the rectified butter or oil of antimony, and the ſpirit of nitre, here put together, are both diſtilled liquors, yet the powder, which reſults from their union, is ſo far fixed, that after 'tis edulcorated with water, 'tis calcined for five or ſix hours; which operation it could not bear, unleſs it had attained to a conſiderable degree of fixation. I here ſuppoſe, with the generality of chymiſts, that the addition of a due quantity of ſpirit of nitre is neceſſary to be employed in making the *Bezoardicum Minerale*. But if it be a true obſervation, which is attributed to *Billichius*, that a *Bezoardicum Minerale* may be obtained without ſpirit of nitre, barely by a ſlow evaporation, (made in a glaſs diſh,) of the more fugitive parts of the oil of antimony; the inſtance will not, indeed, be proper in this place; but it belongs, however, to the ſecond way of introducing fixity. Again, if you take ſtrong ſpirit of ſalt, and ſatiate it with the volatile ſpirit of urine; the ſuperfluous moiſture being abſtracted, you will obtain a compound ſalt, ſcarce, if at all, diſtinguiſhable from ſal-armoniac; and which will not, as the ſalts it conſiſts of, before their coalition, eaſily fly up into the air, but require a conſiderable degree of fire to ſublime it.

I lately mentioned, that the volatility of the ſpirit of nitre may be much abated by coagulating it into cryſtals, with particles of corroded ſilver; I ſhall now add, that ſuch nitrous ſpirits may be made much more fixed by the addition of the ſpirit of ſalt, which, if it be good, will, of it ſelf, fume in the air. For having diſſolved a convenient quantity of cryſtals of ſilver, in diſtilled water, and precipitated them, not with a ſolution of ſalt, but the ſpirit of ſalt, the phlegm being abſtracted, and ſome few of the looſer ſaline particles; though the remaining maſs was urged with a violent fire, which kept the retort red-hot for a conſiderable time; yet the nitrous and ſaline ſpirits were not at all driven away from the ſilver, but continued in fuſion with it; and when the maſs was taken out, theſe ſpirits ſo abounded in it, that it had no appearance of a metal, but looked rather like a thick piece of horn.

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The next inſtance is afforded us by that kind of turbith, which may be made by oil of vitriol inſtead of the *Aqua fortis* employ'd in the common *Turpethum minerale*. For tho' oil of vitriol be a diſtilled liquor, and mercury a volatile body; yet when we abſtracted four or five parts of oil of vitriol from one of quick-ſilver, and then waſhed off as much as we could of the ſaline particles of the oil of vitriol, thoſe which remained, adhering to the mercury, rendered it far more fixed, than either of the liquors had been; and enabled it, even in a crucible, to endure a ſurprizing degree of fire, before it could be driven away. The like turbith may be made with the oil of ſulphur *per campanam*. But this is nothing, to what *Helmont* tells us of the operation of his alkaheſt; where he affirms, that this menſtruum which is volatile, being abſtracted from running mercury, not only coagulated it, but left it ſo fixed, as to endure fires excited by the utmoſt force of bellows. If this be certain, it will not be a ſlender proof, that fixity may be mechanically produced; for if there remain ſome particles of the menſtruum with thoſe of the metal, it will not be denied, that two volatile ſubſtances may perfectly fix one another. And even this will appear leſs improbable from ſome farther inſtances. Having put a mixture, made of a certain proportion of two dry volatile bodies, (*viz.* ſal-armoniac, and very fine powder of ſulphur,) to half its weight of common running mercury, and elevated this mixture three or four times from it, the mercury, which lay at the bottom, in the form of a ponderous, purpliſh powder, was, by this operation, ſo fixed, that it long endured a ſtrong fire, which, at length melted the glaſs, and kept it ſo, without forcing up the mercury; which, by the way, as we found upon ſome trials, ſeemed to have its ſalivating, and emetic powers greatly infringed, and ſometimes quite ſuppreſſed. In the remaining inſtances, I ſhall employ only one menſtruum, oil of vitriol, and ſhew the efficacy of it, in fixing ſome parts of volatile bodies, with ſome parts of itſelf; by which examples it will appear, that a volatile body may not only leſſen the volatility of another body; but that two ſubſtances, which apart were volatile, may compoſe a third, which will be leſs volatile, and even conſiderably fixed. We mixed, by degrees, about equal parts of oil of vitriol, and oil of turpentine; and though each of them ſingle, eſpecially the latter, will aſcend with a moderate fire, in a ſand-furnace; yet after a diſtillation, we had a conſiderable quantity, ſometimes a fifth or ſixth part of a coal-black *Caput mortuum*, able to endure the fire. And to give a higher proof of the diſpoſition, which oil of vitriol hath, to let ſome of its parts grow fixed, by combination with thoſe of an exceeding volatile liquor, I mixed it with an equal or double weight of highly rectified ſpirit of wine, and found, that the fluid parts of the mixture being totally abſtracted, there would remain a conſiderable quantity of black ſubſtance, fixed to admiration. And becauſe camphire is eſteemed the moſt fugitive of conſiſtent bodies, ſince being but laid in the free air, without any help of the fire, it will wholly vaniſh; I tried what oil of vitriol, abſtracted from

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PHYSICS. from camphire would do, and found at the bottom of the retort a greater quantity, than one would expect, of a ſubſtance, black as *pitch*, and wanting almoſt as much of the volatility, as of the colour of camphire; though it appeared not, that any of the gum had ſublimed into the neck of the retort.

From all theſe inſtances it manifeſtly follows, that, in many caſes, there needs nothing to make aſſociated particles, whether volatile or not, become fixed; but either to interweave or intangle them among themſelves, or bring them to touch one another in large portions of their ſurfaces, or by both theſe ways together, or by ſome others, to procure a firm coheſion of ſo many particles, that the reſulting corpuſcles ſhall prove too big or heavy to be driven up into the air, by that degree of fire, wherein they are ſaid to be fixed *.

* Sir *Iſaac Newton*, whoſe words we can never uſe too much, inſtructs us, alſo, in the nature of fixedneſs and volatility. "The particles of "fluids, (ſays that great philoſopher,) which do "not cohere too ſtrongly, and are of ſuch a ſmall-"neſs, as renders them moſt ſuſceptible of thoſe "agitations, which keep liquors in a fluor, are "moſt eaſily ſeparated and rarified into vapour; "and in the language of the chymiſts they are "volatile, rarifying with an eaſy heat, and con-"denſing with cold. But thoſe which are groſ-"ſer, and ſo leſs ſuſceptible of agitation, or co-"here by ſtronger attractions, are not ſeparated "without a ſtronger heat, or perhaps not without "fermentation. And theſe laſt are the bodies "which chymiſts call fixed; and being rarified by "fermentation, become true permanent air: thoſe "particles receding from one another, with the "greateſt force; and being moſt difficultly "brought together, which upon contact cohere "moſt ſtrongly. And becauſe the particles of "permanent air are groſſer, and ariſe from den-"ſer ſubſtances than thoſe of vapours; thence it "is that true air is more ponderous than vapour; "and that a moiſt atmoſphere is lighter than a dry "one, quantity for quantity." *Newton. Optic.* p. 371, 372. Hence eaſily ariſes a rational account of thoſe two chymical operations, diſtillation and ſublimation, which Sir *Iſaac Newton* thus delivers. "When oil of vitriol is mixed with a little wa-"ter, or is run *per deliquium*, and, in diſtillation, "the water aſcends difficultly, and brings over "with it ſome part of the oil of vitriol, in the "form of ſpirit of vitriol; and this ſpirit being "poured upon iron, copper, or ſalt of tartar, u-"nites with the body, and lets go the water; "doth not this ſhew that the acid ſpirit is at-"tracted by the water, and more attracted by "the fixed body than by the water, and there-"fore lets go the water to cloſe with the fixed "body? And is it not for the ſame reaſon that "the water and acid ſpirits, which are mixed "together in vinegar, *Aqua fortis*, and ſpirit of "ſalt, cohere and riſe together in diſtillation; "but if the menſtruum be poured upon ſalt of "tartar, or on lead, or iron, or any fix'd bo-"dy which it can diſſolve, the acid by a "ſtronger attraction adheres to the body and "lets go the water? And is it not alſo from a "mutual attraction, that the ſpirits of ſoot and "ſea-ſalt unite and compoſe the particles of ſal-"armoniac, which are leſs volatile than before, "becauſe groſſer and freer from water; and that "the particles of ſal-armoniac, in ſublimation, "carry up the particles of antimony, which will "not ſublime alone; and that the particles of "mercury uniting with the particles of acid ſpi-"rit of ſalt, compoſe mercury ſublimate, and with "the particles of ſulphur compoſe cinnabar; "and that the particles of ſpirit of wine and "ſpirit of urine, well rectified, unite, and letting "go the water that diſſolv'd them, compoſe a con-"ſiſtent body; and that in ſubliming cinnabar "from ſalt of tartar, or from quick-lime, the ſul-"phur, by a ſtrong attraction of the ſalt or lime, "lets go the mercury, and ſtays with the fixed "body; and that when mercury ſublimate is ſub-"limed from antimony, or from regulus of "antimony, the ſpirit of ſalt lets go the mercu-"ry, and unites with the antimonial metal, "which attracts it more ſtrongly, and ſtays with "it till the heat be great enough to make them "both aſcend together, and then carries up the "metal with it in the form of a very fuſible ſalt, "called butter of antimony, though the ſpirit "of ſalt alone be almoſt as volatile as water, "and the antimony alone as fix'd as lead? --- "When arſenic with ſoap gives a *Regulus*, and "with mercury ſublimate, a volatile fuſible ſalt, "like butter of antimony, doth not this ſhew "that arſenic, which is a ſubſtance totally vo-"latile, is compounded of fix'd and volatile "parts

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" parts, ſtrongly cohering by a mutual attrac-
" tion, ſo that the volatile will not aſcend with-
" out carrying up the fixed? And ſo when an
" equal weight of ſpirit of wine, and oil of
" vitriol are digeſted together, and in diſtil-
" lation yield two fragrant and volatile ſpirits,
" which will not mix with one another, and
" a fixed black earth remains behind; doth
" not this ſhew that the oil of vitriol is com-
" poſ'd of fix'd and volatile parts ſtrongly united
" by attraction, ſo as to aſcend together in the
" form of a volatile and fluid ſalt, till the ſpirit
" of wine attracts and ſeparates the volatile
" parts from the fixed? And therefore, ſince
" oil of ſulphur *per campanam* is of the ſame
" nature with oil of vitriol, may it not be in-
" ferred, that ſulphur is alſo a mixture of vo-
" latile and fixed parts, ſo ſtrongly cohering by
" attraction, as to aſcend together in ſublima-
" tion? By diſſolving flower of ſulphur, in oil
" of turpentine, and diſtilling the ſolution, 'tis
" found, that ſulphur is compoſed of an inflam-
" mable thick oil or fat bitumen, an acid ſalt, a
" very fixed earth, and a little metal. The three
" firſt were found not much unequal to one ano-
" ther, the fourth in an almoſt inconſiderable
" quantity. The acid ſalt diſſolved in water, is
" the ſame with oil of ſulphur *per campanam*, and
" abounding much in the bowels of the earth,
" and particularly in marcaſites, unites itſelf to
" the other ingredient of the marcaſite, which
" are bitumen, iron and earth; and with them
" compounds alum, vitriol, and ſulphur; with
" the earth alone it compounds alum; with the
" metal alone, or metal and earth together, it
" compounds vitriol; and with the bitumen and
" earth, it compounds ſulphur. Whence it
" comes to paſs, that marcaſites abound with
" theſe three minerals. And it is from the
" mutual attraction of the ingredients, that they
" ſtick together for compounding theſe minerals;
" and that the bitumen carries up the other in-
" gredients of the ſulphur, which without it
" would not ſublime? And the ſame queſtion
" may be put concerning all, or almoſt all the
" groſs bodies in nature. For all the parts of
" vegetables and animals are compoſed of ſub-
" ſtances volatile and fixed, fluid and ſolid, as
" appears by their analyſis: and ſo are ſalts and
" minerals, as far as chymiſts have hitherto been
" able to examine their compoſition. *Newton.*
Optic. p. 356—360.

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EXPERIMENTS

Relating to the

Superficial Figures of Fluids.

Various experiments to discover and illuſtrate the phenomena of contiguous fluids.

PErhaps not the thouſandth part of the univerſe, yet known to us, is formed into ſolid bodies; and conſequently all the reſt is made up of celeſtial fluids, and the atmoſpheres of ſolids; and theſe fluids may, poſſibly, have diſtinct ſurfaces: whence, to obſerve and conſider the effects of the agreement and diſagreement which ſuch fluids, as fall under ſenſible obſervation, have, when contiguous to one another, or to the ſurfaces of ſolids, may chance to illuſtrate the formation of thoſe great maſſes of matter, of which the divine architect has formed the parts of the univerſe. I ſhall here therefore nakedly propoſe the experiments I have made, with relation to this matter; leaving it to others to reaſon upon them.

1. Having poured a menſtruum made of fixed nitre, diſſolved by the moiſture of a cellar, into a glaſs pipe, ſealed at one end, and not a quarter of an inch in diameter; that the concave ſurface of the fluid might be the more conſpicuous; we gently poured on it ſome highly rectified ſpirit of wine, which we knew would not mix with, but ſwim above it; and preſently found the figure of the ſurface of the lower liquor changed, and the cavity quite deſtroy'd; the ſurface, which ſeemed, as it were, common to the two contiguous liquors, appearing flat or horizontal. And ſuch a level ſuperficies we had, by putting theſe two liquors together in a much wider glaſs.

2. By employing oil of turpentine, inſtead of the ſpirit of wine, the liquor almoſt loſt its concavity.

3. But common water, being put into the pipe, retained its concave ſurface though we added to it ſome oil of turpentine, and left it long to reſt upon the water.

4. Some pure oil of gum guaiacum, being poured into a ſlender pipe, we found the upper ſuperficies of it concave; like that which

water

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water would have had in the ſame tube. But putting a little water upon *this* oil, it preſently changed the figure of its ſurface, which then became viſibly convex. PHYSICS.

5. Having put ſome oil of tartar into the pipe, and added ſome drops of the oil of guaiacum to it; this liquor did not manifeſtly alter the concave figure of the ſurface of the alkaline liquor, as the oil of turpentine had done. And having warily poured a little water upon the oil of guaiacum, the upper ſuperficies of it changed preſently from concave to convex, ſo that this oil, in the midſt of the other two liquors, appeared like a little red cylinder; which, inſtead of having circular baſes, was protuberant at both ends; but moſt at that which touched the oil of tartar.

6. Some eſſential oil of cloves being put into a new ſlender pipe, and obſerving it to be ſomewhat concave at the top, where it was contiguous to the air, we added a little common water to it, and found the ſurface of the oil alſo to be tumid. And in regard this liquor, as well as the forementioned oil of guaiacum, tho' it were ſo heavy as to ſink in the water, would not do ſo in deliquated ſalt of tartar, we did, into another ſlender pipe, put firſt ſome of this laſt named liquor, then ſome of the aromatic oil; and laſtly, a little common water; and found that the little cylinder of oil, appeared convex at both ends; but more ſo at the upper, where it was contiguous to the water.

7. Into a little ſlender glaſs, that was much longer, but of like bore with the former, we put a ſmall quantity of quick-ſilver, and having taken notice, how the upper ſuperficies ſwelled in the middle, above the level of the parts, where it touched the glaſs, we poured ſome water upon it, and found a manifeſt and conſiderable depreſſion of the ſurface, tho' the protuberance were not quite depreſſed.

8. This experiment having been frequently repeated, ſometimes it ſeemed, that when the aqueous cylinder was much longer, the depreſſion of the mercurial ſurface was ſomewhat greater. But this did not conſtantly happen. We often obſerved, that, tho' a very little water ſufficed, by its contact, manifeſtly to abate the protuberance of the quick-ſilver; yet it had not the ſame effect on that ponderous fluid, as when, being encreaſed almoſt as high as the length of the pipe would permit, a greater weight of it was incumbent on the mercury: for then I manifeſtly perceived, that the ſurface of the quick-ſilver, being depreſſed almoſt to a level, in thoſe parts of it which were near the inſide of the glaſs, there was, about the middle of the ſurface, an elevation of the mercury, that appeared to be rather more than an hemiſphere, and roſe to the height of its full ſemi-diameter above the reſt of the mercurial ſurface; and in that ſtate it continued as long as I thought fit to let it. And leſt this trial ſhould impoſe upon me, I cauſed it to be more than once repeated. I afterwards cauſed the incumbent water to be ſucked up by degrees, and found that when the incumbent water began to be too much ſhortened, the little ſegment of the ſphere, began to be ſomewhat flattened, and ſubſided more and more, as the water was taken off.

9. Having

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PHYSICS.

9. Having conveyed two ſlender pipes into a pneumatical receiver, one of them furniſhed with common water, and the other with quick-ſilver, we cauſed the common air to be well exhauſted, without obſerving any ſenſible change in the concave figure of the water: but as for the quick-ſilver, I knew not what to conclude about it. For having repeated the trial twice or thrice, it ſometimes ſeemed manifeſtly to be more protuberant upon the exhauſtation of the receiver, than when it was put in; eſpecially when its figure was attentively viewed, and the external air ſuffered to re-enter with all convenient celerity. But that which yet kept me doubtful was, that I obſerved upon taking off the air's preſſure from the quick-ſilver, there diſcloſed themſelves ſome little bubbles, which, I feared, we had not been able to free it altogether from, and which might be ſuſpected to have ſome intereſt in the phenomenon. We alſo conveyed into our receiver a clear chymical oil, heavier than water, and whilſt it was contiguous to that fluid, it had a convex ſurface; alſo having placed the pipe furniſhed with both liquors in the pneumatical receiver, we pumped out the air, without finding that the oil ſenſibly altered its protuberant ſurface, as neither did the water loſe the concave figure of its upper ſuperficies.

10. I took fixed nitre, (or ſalt of tartar) reſolved, *per deliquium*, into a tranſparent liquor, and having half filled a clear vial with it, I poured on it a convenient quantity of vinous ſpirit exactly rectified, that no phlegm might occaſion an union betwixt the two liquors, which ought, as ours did, to retain diſtinct ſurfaces, and ſoon regain them, tho' the glaſs were well ſhaken. Then having found by trial that common oil of turpentine, if employ'd in a competent quantity, will not totally diſſolve in ſpirit of wine, and having alſo obſerved, that if this ſpirit of wine be exquiſitely rectify'd, oil will ſink in it; I warily let fall ſome drops of the oil into the ſpirit, and they fell towards the bottom of the glaſs, till their deſcent was ſtopped by the horizontal ſurface of the alkalizate liquor. And becauſe my deſign was chiefly to obſerve the ſuperficial figure of a fluid, encompaſſed by other fluids without touching any ſolid; I ſhall here take notice of the chief phenomena, which were produced of that kind.

Firſt then, if the oil drops were but ſmall, they ſeemed to the eye, exactly ſpherical. For the oil differing but very little in ſpecific gravity from the ſpirit of wine, the drops did but juſt touch the ſurface of the ſubjacent alkali; and the ſame drops being ſo ſmall, their own weight was not great enough viſibly to depreſs them, and hinder that roundneſs, which the preſſure of the ambient ſpirit, or their own viſcoſity, endeavoured to give them. Secondly, If an aggregate of drops were conſiderably bigger than the former, it would manifeſtly reſt upon the alkalizate liquor, as upon a plain, and appear ſomewhat elliptical; the weight of the upper parts depreſſing the drops, and making the horizontal diameter ſomewhat longer than the tranſverſe. Thirdly, If a yet greater proportion of oil were let fall upon the heavy liquor, it would for a pretty while, appear in the form of an imperfect hemiſphere, or ſome other large

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ſection of a ſphere; the lower part being cut off by the horizontal ſurface of the diſſolved ſalt. But, fourthly, if the quantity of oil were not too great, it was pretty to obſerve, that tho' at firſt putting in, it did, perhaps, ſpread itſelf over the ſubjacent liquor, and lie as it were flat upon it; yet it would gradually, by the action of the ſurrounding fluid, concurring with its own tenacity, be raiſed above the ſurface of the liquid nitre, and be reduced to the figure, either of an hemiſphere, or of a greater ſegment of a globe, or of an imperfect ellipſis, according to the bulk or weight of the oil. Fifthly, tho' theſe globules of oil, often readily mixed, when they touched one another; yet ſeveral times we were able to make them touch without uniting, whence we have cauſed them ſo to bear againſt one another's ſurfaces, as manifeſtly to preſs them inwards; tho' being parted, they would preſently reſume their former figure. But in caſe any of theſe oily portions came, by a more preſſing contact, to be united, they would then alter the figures they had while ſeparate, and take another ſuitable to the bulk of the aggregate. Sixthly, if, when a large portion of oil reſted upon the ſaline liquors, the ambient ſpirit was moderately and warily agitated, it was pleaſant to ſee the various figurations, which the convex part of the ſegment of the globe would be put into by the ſhakes, without any viſible ſolution of continuity, or conſiderable motion of the whole body, which would very ſoon recover its former figure. But if the agitation were too ſtrong, ſome portions would be quite broke off, and preſently turned into little globes. PHYSICS.

11. I tried to produce another phenomenon, by putting together, in a large veſſel, with other liquors, two oils (one whereof was from turpentine) which, by reaſon of the oleaginous nature, wherein they agreed, might exactly mix and make a compound liquor; and one being heavier, and the other lighter *in ſpecie* than the water employ'd, might be again ſeparated thereby, and include betwixt them the liquor; which had divided them. But I found that the oils, being once united, would not eaſily be parted; but according to the prevalence of the lighter or heavier ingredient, in the mixture, the compound oil would almoſt totally, either emerge to the top of the water, or lie beneath at the bottom of it: but ſome part of the oil, which was not, perhaps, all uniformly mixed, did not keep in a body with the reſt; but was either ſeparated from the maſs in the form of globules, ſticking to the ſide of the glaſs, had the other part of its ſuperficies, which was contiguous to the water, very variouſly figured, according as the bulk and degree of gravity of the adhering oil, and other circumſtances determined.

Theſe are ſome of the phenomena I obſerved in oil of turpentine, when invironed only with fluids; but if it were permitted to be contiguous to the inſide of the glaſs, and ſo to faſten part of its ſurface to a ſolid, the greater portion of the ſurface, which remained expoſed to one or both of the contiguous liquors, would, partly by their action, and partly by the gravity of the oil itſelf, be put into figures ſo various, and ſometimes ſo extravagant, that it was much more pleaſant to behold them, than it would be eaſy to deſcribe them.

12. Con-

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PHYSICS. 12. Confined fluids may have diſtinct ſurfaces, without having, at leaſt in many poſitions, refractions differing enough, or reflections ſtrong enough, to make the plain which ſeparates them, obvious to the eye. Thus when the oil of tartar, or the nitrous alkali, which I employ'd, happened to be clear and colourleſs, I have, more than once, made highly rectified ſpirit of wine float upon it ſo, that in moſt poſitions, the vial ſeemed to contain but one uniform liquor; the plain that divided the two fluids, being unapt to be diſcerned but in a poſition, wherein the rays of light, paſſing from thence to the eye, fell very obliquely on it: and indeed, when there was no little duſt or other feculency, ſwimming upon the ſurface of the oil of tartar; I could ſcarce convince ordinary ſpectators, that the vial, in two diſtinct regions of it, contained two unſociable liquors.

13. We took a diſſolved alkali, made of nitre and tartar, and deeply tinged it with cochineal; and that the liquors might not only be heterogeneous, but as differing in gravity and denſity as poſſible, we poured thereon a peculiar kind of oil, lighter than ſpirit of wine; and holding the plain where the two liquors were contiguous, in a convenient poſition, in reſpect of the light and the eye, I obſerved it to make a ſtrangely vivid reflection of the incident rays; ſo that this phyſical ſurface, which was flat, looked almoſt like that of quick-ſilver; and when I viewed it by the light of a candle, the bright figure of the flame was ſtrongly reflected, almoſt as from a cloſe ſpecular body; which tempted me to ſuſpect, that there might be ſomething elſe, beſides the bare ſmoothneſs of the ſurface of the alkalizate liquor to produce ſo briſk a reflection; and the rather, becauſe I did not obſerve, that the remains of the ſame tinged alkali, which I kept in another glaſs, nor a portion of the ſame oil, which I had alſo by me in a ſeparate vial, afforded ſo vivid a reflection from its ſurface: tho' I the leſs wondered at this, becauſe of the great diſpoſition to reflect light, which I had formerly obſerved in the fore-mentioned oil, when joined with other liquors. And looking on this fluid, as a body which, tho' it hath all the neceſſary qualities of an oil, does, in regard of its origin, and ſome properties I have found in it, differ from common chymical oils; I was invited the more to obſerve its phenomena, with regard to reflection: and I found, 1. That the confining plain within the tinged alkali and this liquor, did not appear red, itſelf, nor communicate that colour to the image of the flame of a candle, reflected from it. 2. That when I warily ſhook the containing vial, the upper liquor would be reduced into a ſeeming froth, conſiſting of a great number of imperfectly globular bodies, that, after a while, would make a kind of rude phyſical plain; which, tho' neither horizontal, nor ſenſibly ſmooth, would, at its upper ſuperficies, ſend back the incident light with more briſkneſs, than one could expect. And when the ſeeming froth conſiſted of ſmaller particles, theſe, when they were of a certain ſize, and conveniently placed, with regard to the flame of the candle and the eye, would reflect the incident light ſo many ways, and

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and ſo viſibly, that they ſeemed, for multitude and ſplendor, like little ſparkling corpuſcles of poliſhed ſilver. Thirdly, that tho' pure ſpirit of wine be ſo thin a liquor, and our oil ſo light, as to ſwim upon it; yet I found the confining ſurface very ſtrongly reflective. I have alſo found, that ſome other eſſential oils, and particularly an unſophiſticated one of lemmons, did, with our tinged alkali, afford moſt of the ſame phenomena, but not ſo briſk a reflection. PHYSICS.

14. In cold weather we took eſſential oil of aniſeeds, whoſe property it is to coagulate in ſuch weather, and having, in a gentle warmth, brought it to be fluid, we poured it into a ſlender vial more than half filled with common water, which had been, alſo, a little warmed, that the oil might not be too haſtily reduced to its former ſtate. This oil being lighter than ſo much water, and being poured on in a convenient quantity, had its upper ſurface ſomewhat concave, as that of the water was; but the lower ſurface, ſurrounded by the water, was very convex, appearing almoſt of the figure of a great portion of a ſphere. This being done, the vial was ſtopped, and ſuffered to reſt, for ſome time, in a cold place; by which means, the water continuing fluid as before, the oil was found coagulated in a form, approaching to that it had whilſt in a fluid ſtate. It is worth obſerving how great a difference there was between the dull reflection it made, when coagulated, and the fine one it had made, whilſt a liquor.

15. Having obſerved, that quick-ſilver, and rectified *Oleum Petræ*, are, the former of them the heavieſt, and the latter the lighteſt of all the viſible fluids yet known to me; I put ſome diſtilled quick-ſilver into a ſmall vial, and held it in ſuch a poſture, that the incident light was ſtrongly reflected to my eye; I then ſlowly put to it ſome *Petrelæum*, which being well rectified, was very clear; and obſerved, that as this liquor covered the quick-ſilver, there was at the imaginary plain, where they both joined, a briſker reflection, than the quick-ſilver alone had given before. On this occaſion it will not be amiſs to take notice, that either the ſurface of the air it ſelf, as thin and yielding a fluid as it is, or the ſurface of a ſolid, contiguous to included air, or ſome interpoſed ſubtile matter, may reflect the incident rays of light, more ſtrongly, than moſt men would expect. A curious perſon having one day brought me two pieces of a ſolid, tranſparent body, which he had caſually found, in one of which there was a pearl, large, round, and orient; and in the other, one leſs perfect; one of them was opened, when that which had appeared a pearl, was found to be but a cavity, which contained no groſſer a ſubſtance than air. And I have by me, a well-ſhaped piece of thick glaſs, with an aerial bubble in the middle, which by ſome qualities, particularly its ſpear-like ſhape, and vivid reflection, well reſembles a fair, tho' not orient pearl. But in ſuch obſervations, the poſition of the eye, and that wherein the body receives the rays of light, may be very conſiderable. For I have a ſmall ſtone, that being laid flat upon one's hand, or a piece of paper, and looked on directly downwards, appears

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PHYSICS. pears almoſt like a piece of common glaſs, and is tranſparent; but if the eye be ſo placed, that the incident rays of light, by whoſe reflection it is ſeen, fall with a convenient degree of obliquity upon the ſtone, it makes an exceeding pretty ſhew; ſometimes appearing like a fine opal, and ſometimes not very unlike an orient pearl.

16. Having prepared a competent quantity of a reſinous ſubſtance, which looked like high-coloured amber, but was eaſy to melt; we put it into a deep round glaſs, with a wide mouth, and held it by the *fire-ſide*, till it was brought into a fluid ſtate; then we transferred it into a pneumatical receiver, where we preſumed, that this temporary liquor would diſcloſe aerial bubbles, when the preſſure of the air was withdrawn from it; and, accordingly, having cauſed the air to be pumped out by degrees, we found numerous bubbles appear at the top of the liquor, where they made a great froth, many of them being, by reaſon of the viſcoſity of the fluid, very large, and ſeveral of them adorned with the colours of the rain-bow. I cauſed the pumping to be continued, that thoſe bubbles, which had moſt common air in them, and which, therefore, riſe firſt, might get to the top, and the ſubſequent bubbles might meet with more reſiſtance from the liquor ſtill tending to grow cold, and ſo be the more expanded, and yet kept from emerging, by the concretion of the reſinous ſubſtance; and anſwerably to this, we found, that when the ſubſtance had reſumed its conſiſtent form, there were intercepted, between the upper and lower ſurfaces of it, ſome bubbles, which were not ſmall, yet made a conſiderable reflection; notwithſtanding the ſmall quantity of the groſſer particles of the air, that may be ſuppoſed to be contained in bubbles ſo very much expanded.

17. It is taken for granted, that the falling drops of rain are ſpherical, yet their deſcent is ſo ſwift, that I fear, this is rather ſuppoſed, than obſerved; which will be more queſtionable, if hail be but rain frozen, in its paſſage through the air. For it is evident, that the grains of hail are, frequently, of other figures, than truly orbicular. But the ſurface of water may have different figures, accordingly, as it is totally encompaſſed with heterogeneous fluids, or as it is only in ſome places, contiguous to one or more of them. In the former caſe, we found it not ſo eaſy to make an obſervation, becauſe, we know not of any two liquors, (I except mercury) which will not mix either with one another, or with water. We, therefore, cautiouſly conveyed into chymical oil of cloves, ſome portions of common water of different ſizes; taking care, that they might not touch one another; by which means, the oil being tranſparent, and yet ſomewhat coloured, it was eaſy to obſerve, that the ſmaller portions of water, were ſo near totally inviron-ed with the oil, as to be reduced into almoſt perfect globes; thoſe portions, which were ſomewhat bigger, would be of a figure ſomewhat approaching to that of an ellipſis, and thoſe, which were yet larger, tho' they ſeemed to be ſunk almoſt totally beneath the oil, yet they held to it by a ſmall portion of themſelves, whoſe ſurface was eaſily diſtinguiſh-

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able from that of the oil. Theſe larger portions of immerſed water, being almoſt wholly invironed with the other liquor, were by it reduced into a round figure, which was ordinarily ſomewhat elliptical; but more depreſſed in the middle, than that figure. PHYSICS.

18. Having into a ſlender pipe put a little oil of cloves, and upon this ſome oil of turpentine, ſo that the water might, both above and beneath, be touched by heterogeneous liquors; I obſerved not the oil of cloves to be very manifeſtly tumid at the top, nor the lower ſurface of the oil of turpentine to be very convex; from whence it is eaſy to determine the figure of the cylindrical portion of water, intercepted between the two oils.

19. I took oil of aniſeeds, thawed by a gentle warmth, and common water, and having put them together, in a conveniently-ſhaped glaſs, they were ſuffered to ſtand in a cold place, till the oil was coagulated; which done, it was parted from the water; and, by the roughneſs of its ſuperficies, manifeſted, that, when its parts were no longer agitated, and kept eaſily moveable, by the ſubtile permeating matter, or whatever other agent or cauſe it was, to which it owed its fluidity, the contiguous water grew unable to inflect, or otherwiſe place them after the manner requiſite to conſtitute a ſmooth ſurface. And what happened to that part of the oil's ſurface, which was touched by the water, happened alſo to that, which was contiguous to the air; only the aſperity of the latter ſurface differ'd from the other; which, whether it were an accidental, or conſtant phenomenon, farther trial muſt determine. But I have often obſerved, that the upper ſurface of oil of aniſeeds, when this liquor comes to be coagulated by the cold air, was far enough from ſmooth; being render'd very rugged by many flaky particles, ſome of which lay with their broad, and others, with their edged parts upwards.

20. An inequality and ruggedneſs of ſuperficies I have alſo obſerved in water, when, having covered it with chymical oil of juniper, and expoſed it in very cold weather; for, though the oil continued fluid, yet the water, being frozen, had no longer a ſmooth ſuperficies, as whilſt, in its liquid ſtate, it was contiguous to the oil. And the like inequality, or rather a greater, we obſerved in the ſurface of water frozen, which had chymical oil of turpentine ſwimming over it; yet a greater roughneſs may be often obſerved in the ſurfaces of ſeveral liquors, which abound with water, when thoſe liquors, being frozen, their ſurfaces have an immediate contact with the air. Having purpoſely cauſed a ſtrong and blood-red decoction of wood-ſoot to be expoſed in a large glaſs, in a very cold night; I found in the morning, a cake of ice, which was curiouſly figured, being full of large flakes, ſhaped almoſt like the broad blades of daggers, and neatly fringed at the edges. But theſe figures ſeem to be, as it were, imboſſed; being, both to the eye and the touch, raiſed above the horizontal plain of the other ice.

21. I have ſometimes obſerved the like phenomenon in one and the ſame liquor; and particularly not long ſince, in froſty weather, in a vial,

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PHYSICS. where I had long kept oil of vitriol, I perceived, that the cold had reduced far the greateſt part of the menſtruum into a conſiſtent maſs, whoſe upper ſurface was very rugged, and oddly figured, though it lay covered, all over, with a pretty deal of a high-coloured liquor, which was not frozen, or coagulated, nor ſeemed diſpoſed to be ſo, at leaſt in that degree of cold.

22. This may be alſo obſerved in the beſt ſort of what the chymiſts call *Regulus Martis ſtellatus*, where the figure of a ſtar, or one ſomewhat like that of the decoction of ſoot, lately mentioned, will frequently appear imboſſed upon the upper ſuperficies of the *regulus*, and ſuch a raiſed figure I have ſeen on a maſs of *regulus*, made of antimony, without iron. But if to thoſe two bodies, copper alſo be ſkilfully added, the ſuperficies will be often adorned with new figures, according to the circumſtances; tho' the moſt uſual I took notice of, was that of a net, which ſeemed to cover the ſurface of the compounded *regulus*. This, however, is not ſo conſtant, but that I have by me a maſs of a conical figure, conſiſting of two very contiguous, but eaſily ſeparable parts, the lowermoſt whereof, which abounds more in metal, hath its upper ſurface covered with round protuberances, in ſhape and bigneſs, like ſmall peaſe cut in two; and theſe are ſo really imboſſed, and elevated above the reſt of the ſuperficies, that the other part of the cone, which is of a more ſcorious nature, has, *in its* lower ſurface, which exactly fits the upper of the *regulus*, cavities, for number, ſhape, and ſize, anſwering to the protuberances; which argues, that the *regulus* cooled firſt, with that inequality of ſurface, we have deſcribed; and that the lighter, and more droſſy ſubſtance, continuing longer fluid, had thereby an opportunity to accommodate it ſelf to the ſuperficial figure of the *regulus*, on which it firſt reſted, and afterwards coagulated.

THE

THE ATMOSPHERES OF CONSISTENT BODIES.

THAT fluids ſhould ſend out exhalations, will, I preſume, be readily granted, eſpecially conſidering the ſenſible evaporation of water, wine, &c. and the looſe contexture of parts neceſſary to compoſe ſoft bodies; but that hard, and ponderous ſubſtances, likewiſe, emit ſteams, will, perhaps, require to be proved. But though we might *à priori*, both from the *Epicurean* and *Carteſian* philoſophy, ſhew, that conſiſtent bodies are exhalable; it will be more ſatisfactory and uſeful to do it *à poſteriori*, by particular experiments and examples.

Aromatics, and bodies of a looſe texture, exhalable.

That a dry and conſiſtent form does not infer an indiſpoſition to yield effluvia, is evident in all the aromatics, and perfumes, but more eſpecially in camphire, and ſuch volatile ſalts, as are obtained from harts-horn, blood, &c. for theſe are ſo fugitive, that I have had a lump of volatile ſalt fly away, without leaving a grain behind; and I found, that a ſmall piece of camphire would, in a few hours, ſuffer a viſible loſs of weight, by the avolation of ſcented corpuſcles; tho' the experiment was made in a north window, and in the winter ſeaſon. But if inſtances are required from bodies of a cloſe and ſolid texture, I have found, that many electrical bodies, ſuch as amber, roſin, brimſtone, &c. when they are well rubbed, part with numerous corpuſcles; and the common explanation of the attraction of ſuch bodies, ſuppoſes the emiſſion of corporeal particles. I have found ſeveral fruits, &c. even in winter, grow daily lighter in the ſcales, wherein I kept them, noting their decreaſe of weight; but to ſhew, how conſiderable an evaporation is made from wood, I cauſed a thin cup, that would hold a pint, to be turned, of a ſort of it that was not very cloſe, from which, in the winter, there was ſo quick and plentiful an evaporation, that I found it no eaſy matter to counterpoiſe it; for whilſt grains were putting into the oppoſite

And thoſe of a cloſe and ſolid texture.

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PHYSICS. site scale, the great avolation of invisible steams would make the scale that held it, sensibly too light. For farther satisfaction, I ordered a bowl, about the same bigness with the former, to be made of well-seasoned wood, which, being suspended, in my chamber, quickly began to lose of its weight; and though the whole vessel weigh'd but an ounce and three quarters, yet from ten a-clock in the morning to ten at night, it lost about forty grains *. And it were easy to multiply instances of the continual exhalation of steams from vegetable and animal substances; but since those substances are the most unlikely to afford effluvia, that are either very cold, or very ponderous; very solid and hard, or very fixed; if I can shew, that these qualifications cannot keep a body from emitting steams, I shall have made it probable, that all sorts of bodies may afford them. And first, I have not only found eggs, in a very sharp winter, to grow sensibly lighter, but having counterpoised a convenient quantity of ice in an exact balance, and exposed it to the cold air of a frosty night, that the evaporations should be from ice, and not from water, I found, the next morning, its weight considerably diminished; and this experiment I made with the like success in more than one winter, and more than one place.

As also cold bodies.

Various exhalations raised, by means of fire, from solid bodies.

But, by the way, in explaining some occult qualities, such exhalations as are raised by means of fire, may be taken into consideration. Now fire is able to put the parts of bodies into so violent a motion, that except gold, glass, and a very few more, there are none so fixed and solid, but it will dissipate, either totally, or in part. Not only lead and tin, but much harder bodies emit plentiful and noxious steams; and there are some kinds of iron, which our smiths call cold-share iron, whose smell, whilst red-hot, is intolerably strong and rank, in the working. And without being brought to fusion, not only brass and copper will become strongly scented, but common iron also; as is evident by the smell of many iron stoves.

Very ponderous bodies yield effluvia.

To proceed to ponderous bodies; if we allow, that the magnetical operations of the load-stone, for instance, are performed by particles issuing from it; this will serve for an instance to our present purpose, since I have hydrostatically found, that some load-stones have double the weight of flints, or other stones of the same bulk. And stone-cutters will inform us, that black marble, and some other heavy stones, yield a very sensible smell in polishing; and it will be granted, that odours are not diffused without corporeal exhalations. Having procured some of those, which pass among the vulgar for thunder-stones, I could, by rubbing them, excite a strong sulphureous scent. I have also made a certain

* It appears very probable, from an Observation of L. *Lister*, that odoriferous bodies spend their very substance in effluvia. He found great numbers of stones, which lay in several drawers made of *Barbadoes* cedar, were thick covered over with a liquid rosin, like *Venice* turpentine, tho' no manner of exudation appeared in any part of the cabinet. Whence, says the Dr. the whole body of the turpentine of the cedar wood, must have been carried into the air, and floating therein, be again condensed, in its own form, upon these stones. *Philos. Trans.* N°. 110. p. 224.

mineral

mineral maſs, almoſt as ponderous as a metal, emit more ſtrongly ſcented exhalations, than I could well endure. And having once made a chymical mixture of a metalline body, and coagulated mercury, it was ſo diſpoſed to part with corporeal effluvia, that a perſon, who practiſed phyſic, begged a little of it for ſome patients, troubled with diſtempers in the eyes; and afterwards affirmed, that it very happily cured them, by being worn in a ring on the finger, or as an *Appenſum* near the diſaffected part. If we make a *Vitrum Saturni*, with a large quantity of *Minium* in proportion to the ſand or cryſtal, which it helps to fuſe, we ſhall have a glaſs exceeding ponderous, and yet not deſtitute of electricity. And having ſometimes cauſed braſs to be turned, after the manner of wood, to try, whether ſo great a concuſſion would not throw off ſteams, that might be ſmelt, it anſwered my expectation; and a workman, who uſed to turn very great quantities of braſs, informed me, that the ſcent of it in the lath, was ſometimes ſo ſtrong, as to be very offenſive to perſons un-uſed to it.

Very ſolid, hard, and ponderous bodies yield them.

I proceed now to the effluvia of ſolid and hard bodies: and here I may be allowed to inſtance in electrical ones, becauſe they are acknowledged to operate by ſubſtantial effluvia. Now among theſe, I have obſerved many of ſo cloſe a texture, that neither *Aqua fortis* it ſelf, nor ſpirit of ſalt, would work upon them; and to be ſo hard, as to ſtrike fire, like flints. Of the former ſort I have found ſeveral gems, and even cornelian it ſelf; rock cryſtal alſo, though it hath an attractive virtue, is yet ſo hard, as to ſtrike fire, rather better than ordinary flints: and though diamonds are the hardeſt bodies we know, yet frequent experience has aſſured me, that even theſe, are very manifeſtly electrical. There is a ſort of concretions, very well known in ſeveral parts of *Italy*, by the name of *Cugoli*, and much uſed by the glaſs-men. Theſe are very hard, and yet by rubbing them one againſt the other, they afford a very ſtrong ſmell. To which we may add, that ſtrong ſcents are produced by the attrition of *Calculi humani*, iron, marcaſites, pyrites, *&c.* whence it appears, that bodies, capable of being the ſource of corporeal effluvia, may be, at once, very ſolid, and very ponderous. It, therefore, only remains to ſhew, that even fixedneſs in bodies is not incompatible with their diſpoſition to yield exhalations. The *Regulus* of antimony, and alſo its glaſs, though they muſt have endured fuſion, to attain their reſpective forms; yet they will, without heat, communicate emetic and purgative expirations to liquors: and ſeveral electrical bodies are very fixed in the fire; particularly cryſtal will endure ſeveral ignitions, and extinctions in water, without being truly calcined. But becauſe the antimonial bodies juſt mentioned will, after a while, fly away in a ſtrong fire; and becauſe the effluvia of cryſtal are not ſo ſenſible, as thoſe which immediately affect our eyes or noſtrils; I will here ſubjoin an inſtance, which will render others needleſs: for, tho' glaſs is able to endure ſo vehement a fire, yet I quickly found, that by rubbing

And even ſuch as are fixed.

two

PHYSICS. two ſolid pieces of it, againſt one another, they would not only yield a ſenſible, but a ſtrong offenſive odour.

The atmoſpheres of bodies excited by gentle heat.

And as the ſun is the great agent of nature, in the planetary world; and ſince, during the ſummer, and eſpecially at noon, and in ſouthern climates, his heat makes many bodies have little atmoſpheres, that we cannot conſtantly ſo well diſcern; we may very well aſcribe atmoſpheres to ſuch bodies, as have them from the ſun's influence; and allow the like to ſuch other bodies, as will perform the things uſually aſcribed to effluvia, when yet they are excited but by an external heat, which exceeds not that of the clear ſun. Of theſe two ſorts, I ſhall give but two examples.

To ſhew, that the particular and uſual manner of exciting electrical bodies, by rubbing them, is not always neceſſary; I took a large piece of good amber, and having in a ſummer's morning, whilſt the air was yet cold, tryed, that it would not, without being excited, attract a light body, I removed it into the ſun-beams, till they had made it moderately hot; and then found, it had acquired an attractive virtue; and that not only in one particular place, as when it is excited by rubbing, but in ſeveral diſtant places at once; ſo that even in our climate, a ſolid body may quickly acquire an atmoſphere by the preſence of the ſun, and that long before the warmeſt part of the day. I alſo took a little ſmall thick veſſel of glaſs, and held it near the fire, till it had got a convenient degree of heat, whereby it became attractive, as that of the ſun's heat had rendered the amber. Hence it ſeems deducible, that many conſiſtent bodies, whether animal, vegetable, or mineral, may emit effluvia; and that even ſuch as are ſolid may reſpectively have their little atmoſpheres. And ſeveral things induce me to believe, that there are many more bodies of the like nature. For, very few have had the curioſity to make uſe of nice ſcales, to examine the expirations of inanimate bodies; but if they ſhall hereafter, they will doubtleſs find, that ſome bodies, not yet known to yield exhalations, afford them; and that many others part with far more than is uſually imagined. Who would have thought, that ſo extremely a cold body as a ſolid piece of ice, ſhould plentifully evaporate in the cold air of a freezing night; or that a piece of wood, which had long lain in the houſe, and was light enough to be conveniently hung, for a long time, at a very exact balance, ſhould, in leſs than a minute, breathe out ſteams enough to make the ſcales manifeſtly turn, and that in the winter? But, ſuppoſing ſuch trials, made with good inſtruments for weighing; though it is certain, that in caſe the expoſed body grows lighter, ſomething exhales from it; yet it will not follow, if no diminution of weight be diſcovered by the inſtrument, that nothing corporeal recedes from it. For though the loadſtone be concluded to have conſtantly about it a great multitude of magnetical effluvia, which may be called its atmoſphere; yet it hath not been obſerved to loſe of its weight by the avolation of ſo many corpuſcles; and though good amber-greaſe be conſtantly ſurrounded by a large atmoſphere, the waſte of it is ſurprizingly ſmall. If it be ſaid, that

Many more bodies may emit effluvia, and have their atmoſpheres, than is uſually imagin'd.

Bodies may exhale, without manifeſting it by a loſs of weight.

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that in length of time, a decreaſe of weight may appear in bodies, that diſcover none in a few hours or days; the objection, if granted, does not affect our doctrine: it is ſufficient for us to have proved, that the effluvia of ſome bodies may be ſubtile enough, not to make thoſe bodies, by their avolation, appear lighter in ſhort ſtatical trials. And for ought we know, the decreaſe of bodies in ſtatical experiments, long continued, may be greater, than even nice ſcales will diſcover; for how are we ſure, that the weights themſelves, which are commonly made of braſs, may not, in tract of time, ſuffer a little diminution, as well as the bodies counterpoiſed by them? And no man, I think, has yet tried, whether glaſs, and even gold, may not in length of time, loſe of their weight; which in caſe they ſhould do, it would not be eaſily diſcovered, unleſs we had bodies that were perfectly fixed; by comparing them whereto we might be better aſſiſted, than by comparing them with braſs weights, or the like, which, being themſelves leſs fixed, will loſe more than gold or glaſs. PHYSICS.

Laſtly, there may be ſeveral other ways, beſides the ſtatical, of diſcovering the effluvia of ſolid bodies; and conſequently of ſhewing it unſafe to conclude, that becauſe their operation is not conſtant or manifeſt, ſuch bodies never emit any effluvia at all; and ſo are unable to work, by their means, on any other body, though never ſo well diſpoſed to receive their action. And this I the rather obſerve, becauſe my principal deſign was here to illuſtrate the doctrine of occult qualities. It may conduce to explain ſeveral of them, to know that ſome particular bodies emit effluvia, though perhaps they do it not conſtantly and uniformly; and tho' perhaps too, they appear not to have emitted any at all, if examin'd after the ſame manner, with other exhalable bodies; but only may be made to emit them by ſome determinate operation on another ſingle body, or ſmall number of bodies. Without trial, one would not think, that from glaſs there could, by rubbing, be obtained ſuch ſteams, as to offend the noſtrils. Nor ſhould we eaſily believe, if experience did not aſſure us, that a diamond will, by a little rubbing, be made to part with electrical effluvia. Nay, I once had a diamond unpoliſh'd, uncut, and not much bigger than a large pea, whoſe electrical virtue was eaſily excited, by barely paſſing my fingers over it to wipe it: and if, as ſoon as I had taken it out of my pocket, I applied an hair to it, tho' I touched not the ſtone with my fingers, that I might be ſure not to rub it, that hair would be attracted, at ſome diſtance, for ſeveral times ſucceſſively; eſpecially by one of the ſides of the ſtone: and tho' this excitation of the diamond ſeemed to proceed only from the warmth it had acquired in my pocket; yet I did not find this warmth, tho' it ſeemed not to be altered, had always the ſame effect on it; but the wiping it with my finger failed not to excite it. Something like this uncertainty I always obſerved in another diamond, which was much nobler, and very well poliſhed; and alſo in a ſmall ruby, which ſometimes would prove conſiderably electrical, without being

Other ways beſides the ſtatical, of diſcovering the effluvia of ſolid bodies.

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PHYSICS. ing rubbed, when I but wore the ring it belonged to, on my finger; and ſometimes, again, it ſeemed to have loſt that virtue, without my knowing whence ſuch a change ſhould proceed. I have ſeen a ſtone, which I ſhould have judged to be agate, and conſequently, have thought, that it could not communicate medicinal effluvia, fitted to ſtop bleeding, if the wearer of it had not been ſubject thereto; and often cured both himſelf and others, by wearing this ſtone about the neck; and if he left it off, as ſometimes he did for trial-ſake, that would in a few days return. *And it* would probably have never been ſuſpected, that ſo ponderous and ſolid a body as the load-ſtone, ſhould be ſurrounded by an atmoſphere, if iron had been a ſcarce mineral; and had not chanced to have been placed near it. And ſince ſolid bodies may have conſtant atmoſpheres about them, and yet not diſcover, that they have them, but by their operation upon one particular body, or thoſe few which participate of it; and ſince there are, already, very different ways, whereby bodies may appear exhalable; it is not unlikely, that more bodies will, by degrees, be found to emit effluvia, as more ways of diſcovering that they do ſo, ſhall, either by chance or induſtry, be brought to light.

THE

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THE
Nature, Properties, and Effects
OF
EFFLUVIA.

SECT. I.

WHETHER we ſuppoſe, with the ancient and modern atomiſts, that all ſenſible bodies are made up of indiviſible corpuſcles; or whether, with *Ariſtotle* and the *Carteſians*, we grant matter, like quantity, to be indefinitely diviſible; the effluvia of bodies may conſiſt of particles extremely ſmall. According to the opinion of *Ariſtotle* and *Des-Cartes*, no ſtop can be put to the ſubdiviſion of matter; and though the *Epicurean* hypotheſis will have it terminate in certain ſolid corpuſcles, which, for their not being further diviſible, are called atoms; yet the aſſertors of theſe, juſtly think themſelves injured, when they are charged with taking the motes, that float in the ſun-beams, for their atoms; ſince, according to theſe philoſophers, one of thoſe little grains of duſt, that is viſible, only when it plays in the ſun-beams, may be compoſed of a multitude of atoms, and exceed many thouſands of them in bulk. This the learned *Gaſſendus* makes probable, by the inſtance of a ſmall mite; which, tho' ſcarce diſtinctly viſible to the naked eye; yet in a microſcope appears to be a compleat animal, furniſhed with all neceſſary parts; and, I have often, in cheeſe-mites, very diſtinctly ſeen the hair growing upon their legs. Thus much may ſerve to ſhew, that the wonderful minuteneſs, I ſhall hereafter aſcribe to effluvia, is not inconſiſtent with the moſt received theories of naturaliſts: otherwiſe, the proofs I mean to employ, muſt be taken, not *à priori*, but *à poſteriori*.

Now, the experiments and obſervations, to be uſed on this occaſion, will be chiefly ſuch as are referable to the following heads.

1. The ſtrange extenſibility of ſome bodies, whilſt yet their parts remain tangible.

2. The multitude of viſible corpuſcles, that may be afforded by a ſmall portion of matter.

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3. The minuteneſs of the pores at which the effluvia of ſome bodies will enter.

4. The ſmall decreaſe of bulk, or weight, that a body may ſuffer by the loſs of numerous effluvia.

5. The great quantity of ſpace that may, as to ſenſe, be filled by a ſmall quantity of rarified matter.

The ſtrange ſubtilty of effluvia, argued from the fineneſs of ſilver wire.

Among many things that are groſs enough to be the objects of touch, and to be managed with our hands, there are ſome which may help us to conceive a wonderful minuteneſs in the ſmall parts they conſiſt of. I procured ſilver, whoſe ductility is very much inferior to that of gold, to be drawn out to ſo ſlender a wire, that when it was accurately meaſured, nine yards thereof weighed but about a grain, in a very tender balance. And ſince experience informs us, that half an *Engliſh* inch may, by diagonal lines, be divided into 100 parts, capable of being eaſily diſtinguiſhed for mechanical uſes; it follows, that a grain of this ſilver wire may be divided into 64,800 parts; and yet each of theſe will be a true metalline cylinder, which we may very well conceive to conſiſt of a multitude of minuter parts. For, tho' I cou'd procure no gilt wire near ſo ſlender as our ſilver wire; yet a grain of ſome I had by me, was fourteen feet long: at which rate, an ounce wou'd reach about a mile. And if we ſuppoſe the gilt wire, as in probability it might have been drawn, as ſlender as the ſilver wire; the inſtance will be ſtill far more conſiderable: for in this caſe, each of thoſe little cylinders, of which 64,800 go to make up one grain, will have a ſuperficial area, which, except at the baſes, is cover'd with a caſe of gold, that is not only ſeparable from it by a mental operation, but, perhaps, alſo by a chymical one. For, I remember, that from very ſlender gilt wire, tho' I could procure none ſo ſlender as this of mere ſilver, I more than once got out the ſilver; ſo that the golden films, whilſt they were in a liquor that plump'd them up, ſeem'd to be ſolid wires of gold; but when the liquor was withdrawn, they appeared oblong and extremely thin double membranes of the metal; which, with a fine inſtrument, might have been ripp'd open, diſplay'd, and made capable of further diviſions and ſubdiviſions. But tho' each of the little ſilver cylinders, juſt mention'd, muſt not only have its little area, but its ſolidity; yet I ſaw no reaſon to doubt, that it might be very poſſible to have drawn the ſame quantity of metal to a much greater length; ſince even an animal ſubſtance is capable of being brought to a ſlenderneſs much ſurpaſſing that of our wire. An ingenious gentlewoman of my acquaintance, who kept ſilk-worms, had once the curioſity to draw out one of the oval caſes they ſpin, into all the ſilken wire it was made up of; which appear'd in meaſure, to be much above 300 yards, yet weigh'd but two grains and a half; ſo that each cylindrical grain of ſilk may well be reckon'd to be, at leaſt, 120 yards long.

Gilt wire.

Silken threads.

Leaf-gold.

We took ſix leaves of beaten gold, and ſingly meaſuring them with a rule, purpoſely made for nice experiments, we found them to have a greater

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equality in dimenſions, and to be nearer true ſquares than could be well expected: the ſide of the ſquare was, in each of them, exactly three inches and a quarter; which number being reduced to a decimal fraction, *viz.* 3.25 and multiply'd by it ſelf, affords 10.5625 for the area of the ſix leaves. Theſe being carefully weigh'd, in a pair of tender ſcales, amounted, all of them, to one grain and a quarter; and ſo one grain of this leaf-gold was extended to ſomewhat above 50 inches; which differ'd, but about a fifth part, from an experiment of the like nature that I made, many years ago, in a pair of exact ſcales: and ſo ſmall a difference may very well be imputed to that of the pains and diligence of the gold-beaters, who do not always work with equal ſtrength and ſkill; nor upon equally fine and ductile gold. Now, ſuppoſing an inch, divided into an hundred ſenſible parts, to be applied to each ſide of a ſquare inch of this leaf-gold; 'tis manifeſt, that by fine parallel lines, drawn between all the oppoſite points, a grain of gold muſt be diviſible into five hundred thouſand very minute ſquares, but yet diſcernable by a ſharp eye. And if we ſuppoſe the inch divided into two hundred parts; the number of the ſquares, into which a ſingle grain is capable of being divided, will amount to no leſs than two millions.

The ſmall quantity of gold employ'd to gild ſilver wire.

There is yet another way to ſhew the great diviſibility of gold. A refiner, with whom I uſed to deal, informed me, that to an ounce of ſilver he commonly allow'd eight grains of gold, when it was to be drawn into well-gilt wire, as ſlender as a hair; but that if it were to be more ſlightly gilt, ſix grains would ſerve the turn. He alſo ſhewed me a fair cylindrical bar of ſilver, as it was at firſt gilt, whereon the leaf-gold that overlaid the ſurface did not appear to be, by odds, ſo thick as fine *Venetian* paper; yet comparing this with gilt wire, the wire appear'd to be the better gilt of the two; poſſibly becauſe the gold, in paſſing thro' the various holes in the making, was, by the ſides of them, not only extended, but poliſh'd; which made it look more vividly than the unpoliſh'd leaves that gilt the ingot. So that, if we ſuppoſe an ounce of the gilt wire lately mention'd, to have been gilt with ſix grains of leaf-gold, it will appear, by an eaſy calculation, that, at this rate, one ounce of gold, employ'd in gilding wire of that fineneſs, would reach between ninety and a hundred miles. But if we further ſuppoſe, that the ſlender ſilver wire, firſt mention'd, were gilt; tho' we ſhould allow it to have not ſix, but eight grains of leaf-gold to an ounce of ſilver; it muſt be acknowledg'd, that an hollow cylinder of gold, weighing but eight grains, may be ſtretch'd ſo as to reach as far as ſixty times its weight of ſilver wire, which it covers; and conſequently, a grain of that wire having been found to be 27 feet long, an ounce of gold would reach 155 miles, and above an half. And if we yet further ſuppoſe this hollow cylinder of gold to be ſlit along, and cut into as ſlender lifts as poſſible; we cannot deny that the gold may be made to reach a ſtupendous length.

To this view of the minuteneſs of tangible objects, 'twill be proper to ſubjoin ſome inſtances of the ſmallneſs of ſuch as ſtill continue viſible.

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PHYSICS. ſible. But as theſe corpuſcles are, ſingly, too little to have any common meaſure applied to any of them; we muſt eſtimate their minuteneſs by the number of thoſe into which a ſmall portion or fragment of matter may be actually divided; the multitude of theſe, being afforded by ſo inconſiderable a quantity of matter, ſufficiently declaring that each of them, in particular, muſt be ſurprizingly little.

The rariſaction of water, turn'd into vapour.

Water, tho' granted to conſiſt of groſs particles, in compariſon of the ſpirituous and odoriferous ones of ſeveral other liquors, as pure ſpirit of wine, *&c.* yet to ſhew that a ſmall quantity of it may be diſperſed into a multitude of manifeſtly viſible corpuſcles, I more than once tried the rariſaction of it into vapours, by help of an æolipile, wherewith, when I made the experiment the laſt time, the event proved as follows:

We put an ounce of common water into an æolipile, and having ſet it upon a chafing-diſh of coals, we obſerved the time when the ſtream of vapour began to be manifeſt. This ſtream was for a conſiderable time impetuous, as appear'd by the noiſe it made, which would be much increas'd, if we applied to it, at a convenient diſtance, a kindled brand, whereof it would blow up the fire very vehemently. The ſtream continued for about a quarter of an hour, but afterwards the wind had pauſes and guſts for two or three minutes, before it quite ceas'd. And by reaſon of the ſhape of the æolipile, a great portion of the vapours condens'd in the upper part of it, and fell down in drops; ſo that, ſuppoſing they alſo had come out in the form of wind, and the blaſt had not been intermitted towards the latter end, I gueſs'd it might have continu'd, uninterruptedly, for 18 or 20 minutes. And by applying a meaſure to the ſmoke, that came out very viſible, in a form almoſt conical, where it ſeem'd to have an inch or more in diameter; it appear'd to be diſtant from the orifice of the æolipile, about 20 inches, and five or ſix inches beyond that, tho' it were ſpread ſo much as to have four or five inches in diameter, yet the irregular coherent clouds were manifeſtly conſpicuous.

The rariſaction of fewel, turn'd to flame.

After the rariſaction of water turn'd to a vapour, we may conſider that of fewel, when 'tis turn'd into flame.

Having often burn'd ſpirit of wine, and alſo oil, in glaſs lamps, ſo made, that the ſurface of the liquors ſtill continued circular; 'twas eaſy to obſerve, how little the liquor would ſubſide by the waſte that was made of it in about half a quarter of an hour. Yet, if we conſider, that the naked eye, after ſome exerciſe, may, as I have often try'd, diſcern the motions of a pendulum, that ſwings faſt enough to divide a ſingle minute into 240 parts; and conſequently half a quarter of an hour into 1800 parts; if we alſo conſider into how many parts of the time employ'd by a pendulum, the vibrations, ſlow enough to be diſcernible to the eye, may be, mentally, ſubdivided; and if we further conſider, that without intermiſſion, the oil is prey'd upon by an actual flame, and that the particles of it continually furniſh a conſiderable ſtream of ſhining matter, which, with a ſtrange celerity, is always flying away; we may very well

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well conceive that those parts of flame, into which the oil is turn'd, are surprisingly minute; since, tho' the wasting of the oil is in its progress too slow to be perceiv'd by the eye; yet 'tis certain, there is a continual decrease of its depth, its physical surfaces being continually and successively attenuated and turned into flame*. And the strange subtilty of the corpuscles of flame might be more strongly argued, if we should suppose, that, instead of common oil, the flame were nourish'd, as 'tis possible, by a fewel much more compact and durable. PHYSICS.

Gun-powder into smoke, and flame.

Having, in a pair of tender scales, carefully weigh'd out half a grain of gun-powder, we laid it on a tile, and whelm'd over it a vessel of glass, with a brass plate to cover the upper orifice of it; then having fired the gun-powder, we observed, that the smoke of it darken'd, and, as to sense, fill'd the whole cavity of the glass, tho' its basis were eight inches, its perpendicular height above twenty, and its figure far more capacious than if it were conical. And this smoke, not containing it self within the vessel, issued out at two or three little interstices, that were purposely left between the orifice of the vessel, and the plate that lay upon it. This cover we then remov'd, to observe how long the smoke would continue to ascend; which we found it would do for about half a quarter of an hour; and during near half that time, the smoke, continually ascending, seem'd to be, at its going out, of the same diameter with the orifice at which it issued; and it wou'd ascend sometimes a foot, sometimes half a yard, sometimes two feet, or more, into the air, before it dispers'd and vanish'd into it.

Now, considering that the cavity of this round orifice was two inches in diameter, how many myriads of visible corpuscles, may we easily conceive, throng'd out at so large an out-let, in the time above mention'd; since they were continually thrusting one another forwards? And into so many visible particles of smoke, must we admit, that the half grain of powder was shatter'd; besides those multitudes, which, having been turn'd into actual flame, may, probably, be suppos'd to have suffer'd a comminution that render'd them invisible. And to shew that the number of these small particles was exceeding great, I caus'd the glass to be filled with common water, and found it to contain 22 pints; and causing one of those measures of that fluid to be weigh'd, it came so near sixteen ounces, that the computation of the whole water amounted to, at least, 160,000 grains, and consequently 320,000 half-grains. To which, if we add, that this gun-powder would readily sink to the bottom of water, as being *in specie*, probably, twice as heavy; we may guess the space, to which the smoke reach'd, exceeded 500,000 times that which contain'd the unfired powder; and this, tho' the smoke being confin'd in the vessel, was thereby kept from diffusing it self so far as, by its streaming out, it shou'd seem it wou'd have done.

* An inch of candle, when converted into light, is, according to *Dr. Nieuwentyt*'s calculation, in his *Religious Philosopher*, divided into 269,617,040 parts.

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The wonderful minuteneſs of the parts in the firſt rudiments of a mite.

To theſe inſtances, from inanimate bodies, I ſhall add one taken from animals. Thoſe, who have, from time to time, open'd eggs that have been brooded upon by a hen, cannot but have obſerved, how ſmall a proportion the chick bears to the bulk of the whole egg; when that which Dr. *Harvey* calls the *Punctum ſaliens*, diſcloſes the motion of the heart, and the colour of the blood; and that even about the ſeventh or eighth day, the whole chick, now viſibly form'd, bears no great proportion to the whole egg, which is to ſupply it with aliment, not only for its nouriſhment, but ſpeedy growth for many days after.

Now, having ſeveral times found, that cheeſe-mites themſelves are generated of eggs; if we conceive, that in theſe eggs, as in ordinary ones, the animal, at its firſt formation, bears but a ſmall proportion to the bulk of the whole egg; the remaining part being to ſuffice for the food and growth of the embryo, probably for a conſiderable time; (ſince, if an ingenious perſon, whom I deſired to watch them, did not miſ-inform me, they uſe to be about ten or twelve days in hatching;) and as this whole egg it ſelf will be allowed to be but little, with regard to the mite it came from; how extreamly and unimaginably minute then, may we ſuppoſe thoſe parts to be, that make up the alimental liquors, and even the ſpirits, that, paſſing through the nerves, ſerve to move the limbs and organs of ſenſe, of but, as it were, the model of ſuch an animal, as when it reſts, wou'd not it ſelf be viſible to the naked eye?

A ſubtile diviſion of a grain of copper.

We carefully weigh'd, in a pair of tender ſcales, one grain of copper filings, and made a ſolution thereof in the ſpirit of ſal-armoniac; having found by former trials, that this menſtruum wou'd give a far deeper blue colour, than either *Aqua fortis*, or *Aqua regia*. This liquor, of which we uſed a large portion, that all the copper might be throughly diſſolved, we put into a tall cylindrical glaſs, about four inches in diameter, and, by degrees, pour'd to it of diſtill'd water, which is more proper, in this caſe, than common water, till we had almoſt fill'd the glaſs, and ſaw the colour grow ſomewhat pale; and then we warily pour'd this liquor into a conical glaſs, that it might be the more eaſy to fill the veſſel ſeveral times to the ſame height. This conical glaſs we filled to a certain mark, four times ſucceſſively; weighing it and the liquor too, as often, in a pair of excellent ſcales, purpoſely made for ſtatical experiments; and which, tho' ſtrong, wou'd, when not too much loaden, turn with about one grain. Theſe ſeveral weights of the glaſs, together with the contain'd liquor, we added together; and then carefully weighing the empty glaſs again, deducted four times its weight from the ſum, and thereby found the weight of the liquor alone to be 28,534 grains; ſo that a grain of copper, which is not half ſo heavy *in ſpecie* as fine gold, communicated a tincture to 28,534 times its own weight.

But as the deſign of my experiment was to ſhew into what a number of parts one grain of copper might be divided; this multitude of parts muſt be eſtimated by the proportion, not ſo much in weight, as in bulk,

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of the tinging metal to the tinged liquor; and conſequently, ſince hydroſtatical trials have informed me, that the weight of copper to the weight of water, of the ſame bulk, is nearly, as nine to one; a grain of copper is in bigneſs, but the ninth part of as much water as weighs a grain; and ſo our number of the grains of tinged water muſt be multiplied by nine, to give us the proportion between the tinging and tinged bodies; that is, a ſingle grain of copper gave a blueneſs to above 256,806 parts of limpid water, each of them as big as it. Which, tho' it may ſeem ſcarce credible, yet I thought fit to proſecute the experiment farther, by pouring all the liquor out of the tall cylindrical glaſs into another clean veſſel, whence filling the conical glaſs twice, and emptying it as often into the ſame cylindrical glaſs, the third time I filled the conical glaſs with colourleſs diſtilled water, and pouring that alſo into the cylindrical glaſs, we yet found the mixed liquor to have a manifeſt blueneſs. And, laſtly, throwing away what was in the cylindrical glaſs, we poured into it out of the ſame conical glaſs, equal parts of diſtilled colourleſs water, and of the tinged liquor, we had formerly ſet apart in the clean veſſel, and found, that tho' the colour were very faint, yet an attentive eye could eaſily diſcern it to be bluiſh; and ſo it was judged by a ſtranger who was brought in to look upon it, and deſired to ſay of what colour he thought it: whence it appears, that one grain of copper was able to impart a colour to above double the former quantity of water. PHYSICS.

This experiment I have been the more particular in relating, both becauſe it is new and becauſe without circumſtances, it would ſeem as incredible as 'tis ſurprizing, that a portion of matter ſhould be able to impart a conſpicuous colour to above 256,806 times its bulk of water, and a manifeſt tincture to above 385,200, and a faint, but yet diſcernible and diſtinguiſhable colour, to above 530,620 times its bulk of water.

Another of a grain of gold.

We alſo took a grain of refined gold, and having diſſolved it without heat, in a ſufficient quantity of good *Aqua regia*, we put to it about two ſpoonfulls of water; and then, by a thread, we hung in the mixture a ſmall piece of a clean metalline body, and kept it ſuſpended in the liquor for many hours. By this means we obtained a precipitate of a fine deep colour, ſo large and light, that it was a long time before it would all ſettle to the bottom. Then, looking upon the remaining part of the ſuſpended metalline body, we found it ſo very little leſs than when the whole was firſt put in, that the diminution of it was not judged to amount to near a grain. By which experiment it appeared, that one grain of gold, not ſwimming in parts ſeparately inviſible, as in ſolutions, but reduced to a manifeſt powder, ſeemed to make a conſiderable quantity of precipitate, at the bottom of the cylindrical vial, its diameter, about an inch, wherein we kept it. And this glaſs, being a little ſhaken, the precipitate would riſe like mud, and be ſo thoroughly diſperſed, in the form of a powder, through the whole body of the liquor, and a

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PHYSICS. greater quantity of water added to it, that at firſt it ſeemed opake, and, after ſome time, appeared like a high purple ſolution. So that one grain of gold, (for the colour ſhew'd there was ſome of that metal *in* every corpuſcle of the precipitate) was reduced into as many grains of powder, as ſufficed to lodge themſelves in all the particles of viſible ſpace, contain'd in a maſs of two ounces of water.

Animal effluvia affect the human body.

It is deliver'd by approv'd writers, that ſeveral perſons, by barely holding dry'd cantharides, for ſome time, in their hands, have *felt much* pain at the neck of the bladder, and had ſome other urinary parts *ſenſibly* injured; which effects are certainly due to material effluvia, that to get into the maſs of blood, muſt paſs through the pores of the ſkin.

Scaliger relates, that in his country, *Gaſcony*, there are ſuch virulent ſpiders, that if a man treads upon them to cruſh them, their poiſon will paſs thro' the ſoles of his ſhoes: and *Piſo*, in his hiſtory of *Brazil*, having ſpoken of a venomous fiſh of that country, and the antidotes he had ſucceſsfully uſed againſt its poiſon; he proceeds to another, which, he ſays, has this wonderful property, "by the ſlighteſt touch of the hand, "or even of the foot of him who bruiſes it through the ſhoe, to "cauſe a palſy, and a numbneſs, like the *European* torpedo, tho' leſs "laſting."

But tho' the torpedo's affecting the ſtriker at a diſtance, ſeems owing to the ſtupefactive, or other venomous exhalations iſſuing from the animal, irritated by the ſtroke, and breathed in together with the air they infect; yet their benumbing or otherwiſe affecting the arm that ſtruck it, rather than any other part, ſeems to argue that the poiſonous ſteams get in at the pores of the ſkin of the limb, and ſo ſtupefy, or otherwiſe injure the nervous or muſcular parts of it*. But that ſome effluvia, even of ſolid bodies, may be ſubtile enough to paſs the pores of the cloſeſt ſubſtances, appears from thoſe of the load-ſtone, which are, by magnetical writers, ſaid to penetrate, without reſiſtance, all kinds of bodies. And tho' I have not tried this in all ſorts, yet having found it true in metals, I am apt to think the general rule admits of very few exceptions; eſpecially if that can be fully made out, which is affirmed about the perviouſneſs of glaſs thereto. For glaſs is generally reputed to be as cloſe a body, as any in nature; and, I have, by trials, purpoſely made, had occaſion to admire the cloſeneſs of very thin pieces of it. But in dials and ſea-compaſſes, which are covered with plates of glaſs, it will be pretended, that the needle may be readily moved by a load-ſtone held over it; becauſe theſe plates being commonly faſtened only with wax, or at beſt with cement, the magnetical effluvia paſs not through the glaſs, but through that much more pervious matter employ'd to ſecure the junctures, only, from the entrance of the air. To clear this mat-

Even the effluvia of ſolids may penetrate ſolids.

* The numbneſs occaſioned by the torpedo proceeds from nothing more than an exceeding ſwift ſtroke, which the creature uſually gives, in order to kill or ſtupefy its prey, by means of two particular muſcles, whoſe office it is; whence the nerves are, by a communication of this motion, affected in a peculiar manner. M. *Reaumur* gives a very full account of this matter in the *French Memoirs*, *A.* 1714. p. 447.

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ter, I cauſed ſome needles to be hermetically ſealed up in glaſs pipes, which being laid upon the ſurface of water, whereon they would lightly float, the included needles did not only readily anſwer to the load-ſtone externally applied, tho' a weak one, but comply'd with it ſo well, that I could eaſily lead, without touching it, the whole pipe to what part of the ſurface of the water I pleaſed. I alſo found, that by applying a better load-ſtone to the upper part of the ſealed pipe, with a needle in it, I could make the needle leap up from the lower part, as near to the load-ſtone as the interpoſed glaſs would give it leave. But I thought it more conſiderable to manifeſt, that the magnetical effluvia even of ſuch a dull body as the globe of the earth, would alſo penetrate glaſs. And this I attempted after the following manner: I took a cylindrical piece of iron, about the bigneſs of one's little finger, and between half a foot and a foot long; having formerly found that the quantity of unexcited iron forwards its operation upon excited needles; and having hermetically ſealed it up in a glaſs pipe, but very little longer than it, I ſuppoſed, that if I held it in a perpendicular poſture, the magnetical effluvia of the earth, penetrating the glaſs, would make the lower extreme of the iron anſwerable to the north pole; and therefore, having applied this to that point of the needle, in a dial or ſea-compaſs which looked towards the north, I preſumed, it would drive it away; which accordingly it did. And having for farther trial inverted the included iron, and held it in a perpendicular poſture, juſt under the ſame point, that extreme of the iron rod, which before had driven away this point, being by inverſion become a ſouth pole, attracted it; from which ſudden change of poles, merely upon the change of ſituation, it alſo appeared, that the iron owed its virtue only to the magnetiſm of the earth; not that of another load-ſtone, which would not have been thus eaſily alterable.

PHYSICS.

Another proof of the great ſubtilty of effluvia, ariſes from the ſmall decreaſe of weight or bulk that a body may ſuſtain by parting with great numbers of them. That bodies infuſed in liquors impregnate them with new qualities, do it by imparting to them ſomewhat of their own ſubſtance, will, I preſume, be readily granted by thoſe, who conceive not how one body ſhould communicate to another a ſolitary naked quality, unaccompanied by any thing corporeal to ſupport and convey it. Glaſs of antimony, and *Crocus Metallorum*, being either of them infuſed in a great proportion of wine, will make it vomitive; and if that liquor be poured off, and new put on, every freſh portion of it will be impregnated with the ſame virtue; and this, tho' the liquor be changed abundance of times: yet the antimonial glaſs, or *Crocus*, are ſaid to continue the ſame, as well in weight as virtue. But I doubt whether the experiment have been exactly made; for the moſt ingenious phyſicians, whom I have queſtioned about it, acknowledg'd the taſt, and ſometimes the colour of the wine to be altered, by the infuſed mineral. However, ſince after repeated infuſions, the mineral ſubſtance is not yet ſenſibly diminiſhed in bulk or virtue, 'tis a proper inſtance: for, that there is a powerful emetic quality im-

Large effluvia may but little alter the weight, or bulk of bodies.

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PHYSICS. parted to the liquor, is manifeſt by experience; and that the mineral does not impart this virtue by irradiation, as *Helmont* ſpeaks, but by ſubſtantial efflux, ſeems, to me, very probable; not only becauſe 'tis hard to conceive how it can be done otherwiſe, but becauſe, as we obſerved, the wine often changes colour, by keeping a competent time upon the mineral, as if it drew thence a tincture: and, even when it is not diſcolour'd, I think it unſafe to conclude, that the menſtruum has not wrought upon it; for I have kept good ſpirit of vinegar, a conſiderable time, upon finely powdered glaſs of antimony, made *per ſe*, without finding this ſpirit to be at all tinged; tho' 'tis known, that antimonial glaſs is ſoluble in ſpirit of vinegar, as mine afterwards appeared to be, by a longer digeſtion in the ſame liquor. But there may be a great number of minute particles diſſolved in the menſtruum, before they become numerous enough to change the colour of it. Thus, tho' too great a quantity of the prepared antimony be put into the liquor, yet it will not be thereby made too ſtrongly emetic. For, the wine, being a menſtruum, will, like other menſtrua, be impregnated but to a certain meaſure, without diſſolving the overplus of the matter put into it. And ſteel, which is a harder and heavier body than glaſs of antimony, is itſelf in part, readily ſoluble, in rheniſh, or other white wine, and ſometimes even in water.

'Tis mentioned by *Helmont*, and has been tried by more than one of my acquaintance, that mercury imparts to water or wine, wherein it has been long infuſed or boiled, the faculty of deſtroying worms; without ſuffering any diminution of its ſubſtance.

Having, in a pair of exact ſcales, ſuſpended a piece of ambergreaſe, bigger than a walnut, and weighing above an hundred grains, I could not, in three days and an half, that I had opportunity to make the trial, diſcover any decreaſe of weight; tho' ſo rich a perfume lying in the open air, was likely, in that time, to have parted with many odoriferous ſteams. And, a while after, ſuſpending a lump of *Aſa fœtida*, for five days and a half, I found it not to have ſuſtained any diſcernible loſs; tho', notwithſtanding the unfavourable cold ſeaſon, it had about it an atmoſphere, repleniſh'd with fetid exhalations: and when, 12 or 14 hours after, perhaps upon ſome change of weather, I came to look upon it, tho' I found the equilibrium ſomewhat alter'd, yet the whole lump had not loſt half a quarter of a grain; which induced me to think, there may, perhaps, be ſteams diſcernible by our noſtrils, that are far more ſubtile than the odorous exhalations of ſpices. For having, in very good ſcales, ſuſpended in the month of *March*, an ounce of nutmegs, they loſt, in about ſix days, five grains and a half; and an ounce of cloves, in the ſame time, loſt ſeven grains and five eighths.

It will doubtleſs render it more probable, that a ſmall quantity of matter being ſcattered into inviſible effluvia, may be exceedingly rarified and expanded, if I can ſhew that it may, for a conſiderable time, emit multitudes of viſible parts, and that in ſo cloſe an order among themſelves,

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as to ſeem, in their aggregate, but one intire liquor, endow'd with a ſtreaming motion, and a diſtinct ſuperficies, wherein no interruption is to be ſeen, even by an eye placed near it. I was induced to deviſe ſuch an experiment, by conſidering, that all the total diſſolutions, hitherto made of pigments, have been in liquors naturally cold, and conſiſting probably of much leſs ſubtile, and certainly of much leſs agitated parts, than that fluid aggregate of ſhining matter, we call flame; whence I argued, that if I could once totally diſſolve a body compoſed of parts, ſo minute as thoſe of a metal, into actual flame, and huſband this flame ſo, that it ſhould not immediately waſte, I ſhould thereby diſſolve the metal in a far more ſubtile menſtruum than common water, *Aqua fortis*, *Aqua regia*, or any other known menſtruum I have yet employed: and conſequently, the attenuation of the metal, in this fiery menſtruum, would much ſurpaſs, not only what happens in ordinary metalline *ſolutions*, but poſſibly alſo, what I have noted about the ſtrange diffuſion of copper diſſolv'd in ſpirit of ſal-armoniac and water. In proſecution of this deſign, I ſo prepared one ſingle grain of that metal, as to diſſolve it in about a ſpoonful of an appropriated menſtruum; and having cauſed a ſmall glaſs lamp to be purpoſely blown to contain this liquor, and fitted it with a ſocket and wieck, ſo that it burnt with a large flame, and very hot, tho' without conſuming the wieck; ſeeming all the while of a greeniſh blue, as if it were but a finer and ſhining ſolution of copper; yet this one grain of prepared metal tinged the flame that was inceſſantly produced, during no leſs than half an hour and ſix minutes. Now, if we conſider, that in this flame there was an uninterrupted ſucceſſion of multitudes of coloured particles, newly extricated, and flying off in every of thoſe many parts, wherein a minute of time may either actually or mentally be divided; if we conſider flame as a light, and very agitated body, paſſing with a ſtream upwards, through the air; and, laſtly, if we only regard the quantity of liquor that would run through a pipe of much leſs diameter than that flame, within the compaſs of the ſaid time; what a quantity of the ſtreaming fluid, we call flame, if it could have been preſerved and collected into one body, may we ſuppoſe would appear to have iſſued from one grain of copper, in the ſpace of 36 minutes? And what a multitude of metalline corpuſcles may we ſuppoſe to have been ſupply'd to tinge that flame during ſo long a time? ſince a cylindrical ſtream of water, falling but through a very ſhort pipe of glaſs conſtantly ſupply'd with liquor, paſſed at ſuch a rate, that though the aqueous cylinder ſeemed more ſlender, by two thirds, than the flame; yet we eſtimated, by the help of a minute-watch, and a good pair of ſcales, that the water effluxed in 36 minutes, would amount to above 72 pounds.

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The laſt ſort of inſtances, I ſhall produce, to ſhew the ſtrange ſubtilty of effluvia, is, of ſuch as diſcover the great quantity of ſpace that may, by a ſmall quantity of matter, when rarified and diſperſed, be either filled, as to ſenſe, or, at leaſt, made the ſphere of its activity.

A large quantity of ſpace may be poſſeſſed by a very ſmall one of rarified matter.

'Tis

PHYSICS. 'Tis ſurprizing to obſerve, with what ſagacity ſpaniels take notice of, and diſtinguiſh, by the ſcent, the places where partridges, quails, &c. have lately been; and I have much wondered at the quick noſe of an excellent ſetting-dog, who, by his way of ranging, and other motions, eſpecially of his head, would not only intimate to us the kinds of game whoſe ſcent he chanced to light on, but diſcover to us where partridges had haunted, ſeveral hours before; and aſſiſt us to gueſs how long they had been gone before we came.

I have heard ſtrange things, in *Ireland*, from thoſe who there make a gain of killing of wolves, about the ſagacity of that peculiar race of dogs they employ in hunting them. But not truſting much to thoſe relators; a very ſober and diſcreet gentleman of my acquaintance, who has often occaſion to employ blood-hounds, aſſures me, that if a man have but paſſed over a field, the ſcent will lie ſo as to be perceptible to a good dog of that ſort for ſeveral hours after. And an ingenious hunter informs me, he has obſerved that the ſcent of a flying and heated deer will ſometimes continue upon the ground from one day to the next.

We may here obſerve, 1. That the ſubſtance left upon the graſs or ground by the tranſient tread of a partridge, hare, &c. probably communicates to the graſs, or ground, but ſome of thoſe effluvia that tranſpire out of their feet, which being ſmall enough to eſcape the diſcernment of the eye, may, probably, not amount to one grain in weight, or, perhaps, not to the tenth part of it. 2. That the parts of fluid bodies are perpetually in motion, as alſo the inviſible particles that ſwim in them, as may appear by the diſſolution of ſalt or ſugar in water; and the wandering of aqueous vapours through the air, even when the eye perceives them not: And, 3. That tho' the atmoſphere of one ſmall parcel of this exhaling matter, may often be very large, in compariſon of the body which throws it out; as may be gueſſed by the diſtance at which ſome ſetters or blood-hounds will find the ſcent of a partridge or deer; yet in places expoſed to the free air or wind, 'tis very likely that theſe ſteams are carried away from their fountain to maintain the forementioned atmoſphere, for eight or more hours; that is, as long as the ſcent has been obſerved to lie, a continual recruit of ſucceſſive ſteams is requiſite. And ſo very ſmall a portion of matter, as the fumes of thoſe ſteams may be ſuppoſed, being ſenſibly to impregnate an atmoſphere incomparably greater than itſelf, and ſupply it with almoſt continual recruits, we cannot but think the ſteams it parts with, muſt be extremely minute.

We may farther conſider, that the ſubſtances which emit theſe ſteams, being ſuch as lately belonged to animals, and were, for the moſt part, tranſpired through the pores of their feet, muſt, in likelihood, be a far more evaporable and diſſipable kind of bodies, than minerals or burnt vegetables, ſuch as gun-powder is made of; ſo that if the grains of gun-powder emit effluvia, perceptible to the ſcent of ſome animals, it may be probably ſuppoſed, that the ſmall grains of this powder will continue much

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much longer to ſupply an atmoſphere with odorable ſteams, than the corpuſcles left on the ground by tranſient animals. Now tho' it be generally allowed, that very few birds have the ſenſe of ſmelling, any thing near ſo quick as ſetting-dogs, or blood-hounds; yet that the odour of gun-powder, eſpecially when aſſiſted by the ſteams of the *Caput mortuum* of powder, formerly fired in the ſame gun, may, by fowls, be ſmelt at a conſiderable diſtance, particularly, when the wind blows from thence to them; I have often been perſwaded, from my own experience in ſhooting; and was confirmed in that opinion by ſober and ingenious perſons, much exerciſed in the killing of wild fowl, and other creatures. PHYSICS.

There is an obſervation of the experienced *Julius Palmarius*, whence we learn that beaſts may leave upon vegetables, that have touched their bodies for any time, ſuch corpuſcles, as tho' unheeded by other animals, may, when eaten, produce in them the diſeaſes of the infected animals: for this author writes, in his uſeful treatiſe of contagious diſtempers, that he obſerved horſes, oxen, ſheep, *&c.* to run mad upon the eating ſome of the ſtraw on which mad ſwine had lain. *Contagious effluvia.*

But the effluvia ſmelt by animals are, tho' inviſible, big enough to be the objects of ſenſe; whence, 'tis not improbable, that among the ſteams which no ſenſe can immediately perceive, there ſhould be ſome far more ſubtile than theſe, and conſequently capable of furniſhing an atmoſphere much longer, without quite exhauſting the effluviating matter that afforded them. *Foreſtus* gives us an example of peſtilential contagion long preſerved in a cobweb. *Alexander Benedictus* writes alſo, that at *Venice* a flock-bed did, for many years, harbour a peſtiferous malignity, to ſuch a degree, that when, afterwards, it came to be beaten, it preſently infected the by-ſtanders with the plague. And *Sennertus* relates, that in the year 1542, in the city of *Breſlaw*, where he afterwards practiſed phyſic, there died of the plague, in leſs than ſix months, almoſt ſix thouſand men; from which time, the peſtilential contagion was kept, folded up in a linen cloth, about 14 years; and afterwards, being unfolded in another city, it began a plague there, which infected, alſo, the neighbouring towns, and other places. *Trincavella* makes mention of a yet more laſting contagion, (which occaſioned the death of ten thouſand perſons) that lay lurking in ſeveral ropes, with which, at *Juſtinopolis*, thoſe who dy'd of the plague had been let down into their graves.

'Tis, indeed, the opinion of ſeveral phyſicians, that the contagion cannot laſt above twenty days, if the body, it adheres to, be expoſed to the free air and the wind; yet a contagion may, ſometimes, happen to be much more tenacious and obſtinate. The learned *Diemerbroeck* aſſures us, that his own apothecary, having but removed with his foot, from one ſide to the other of a little arbour, ſome ſtraw that had lain under the bed, wherein, about eight months before, a ſervant of the apothecary's, who recovered, had been ſick of the plague; the infectious ſteams preſently invaded the lower part of his leg, and there produced a pungent pain, and a bliſter, which turned to a peſtilential carbuncle, that could

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PHYSICS. could ſcarce be cured in a fortnight; tho', during that time, the patient were neither feveriſh, nor, as to the reſt of his body, indiſpos'd. This memorable inſtance, together with ſome other of the like kind, that our author obſerved, extorted from him this confeſſion. "Hence the doctrine "of phyſicians, as to the contagion lurking in a proper ſubject, receives "a confirmation; tho' 'tis ſurprizing that this contagion ſhould remain "ſo long in the ſtraw; ſince it had been expoſed to the wind and the "rain, the ſnow and the cold of a whole winter."

In the laſt place, I ſhall obſerve, that ſuch as are ſkilful in *perfuming* of gloves imbue them with but an inconſiderable quantity of odoriferous matter; yet I have long had by me a pair of ſpaniſh gloves, which, in different hands have been preſerved near thirty years; yet are, at preſent, ſo well ſcented, that they probably will continue fragrant for many years longer. Now, as ſuch gloves cannot have been carried from one place to another, or ſo much as uncover'd in the free air, without diffuſing a fragrant atmoſphere; we muſt conclude thoſe odoriferous ſteams to be unimaginably ſubtile, that cou'd, for ſo long a time, iſſue out in ſuch ſwarms from a little perfumed matter lodg'd in the pores of a glove, and yet leave it richly ſtock'd with particles of the ſame nature; tho' I never, ſince I had them, ſo much as ſhut them up in a box.

SECT. II.

The great efficacy of effluvia.

THOSE who truſt too much to the negative information of their ſenſes, without ſufficiently conſulting their reaſon, having commonly but a ſlight opinion of the power and efficacy of effluvia; imagining that ſuch minute corpuſcles, as are not uſually able to work upon the tendereſt and quickeſt of the ſenſes, cannot have any conſiderable operation upon their bodies. But this ſuppoſition is as ill grounded as it is prejudicial: for tho', *cæteris paribus*, the greatneſs of bodies, in moſt caſes, contributes to that of their effect upon others; yet matter being in its own preciſe nature, an unactive ſubject, one part of the maſs acts upon another, only upon account of its motion, whoſe operations are facilitated, and otherwiſe diverſified by the ſhape, ſize, ſituation and texture, both of the agent and of the patient. And therefore, if corpuſcles, tho' very minute, be numerous enough, and have a competent degree of motion, they may, eſpecially if fitly ſhaped, when they meet with a body diſpoſed to admit them, and receive their impreſſions, perform ſuch things in the patient, as viſible and much groſſer bodies, but leſs conveniently ſhaped and moved, wou'd be utterly unable to effect.

The ſeveral ways whereby the effluvia of one body may act upon another.

There are at leaſt ſix ways, by which the effluvia of a body may remarkably operate upon another; as, 1. By the great number of corpuſcles

puſcles emitted. 2. By their penetrating and pervading nature. 3. By their celerity, and other modifications of their motion. 4. By the fitneſs and indiſpoſition of their bulk and ſhape, to the pores of the bodies they are to act upon. 5. By the motions of one part upon another, which they excite, or occaſion, in the body they work upon, according to its ſtructure. 6. By the fitneſs and power they have to make themſelves be aſſiſted, in their operation, by the more general agents of the univerſe. And tho' there are ſeveral caſes, wherein a body, that emits particles, may notably affect another body, by one of theſe ſingle ways; yet the great effects are uſually produced by the aſſociation of two, three, or more of them: ſo that when I inſiſt upon one, I muſt not be underſtood to exclude the reſt.

The number of agents may ſupply their want of bulk.

Now, ſince, as we have ſeen, the effluvia of a body may be extremely minute; a ſmall portion of matter may, conſequently, emit great multitudes of them: and that the number of agents may, in many caſes, ſupply their want of bulk, eſpecially where they jointly act, or reſiſt, appears from ſome familiar inſtances.

We ſee, that not only the leſſer land-floods that overflow the neighbouring fields, but thoſe terrible inundations, which ſometimes drown whole countries, are made by bodies, ſingly ſo ſmall and inconſiderable as drops of rain, when they continue to fall in thoſe multitudes, we call ſhowers. So the aggregates of ſuch minute bodies, as grains of ſand, being heap'd together in ſufficient numbers, make banks whereby the greateſt ſhips are ſometimes ſplit, and, in moſt places, the ſea itſelf is bounded. And tho' a ſingle corn of gun-powder, or two or three together, are not of force to do much miſchief; yet two or three barrels of thoſe corns, taking fire together, are able to perform prodigious things. Aqueous vapours are look'd upon as the leaſt active effluvia we know; yet when multitudes of them are, in rainy weather, diſpers'd thro' the air, and thereby qualify'd to work on the bodies expos'd to it, their operations are very conſiderable, not only in the diſſolutions of ſalts, and the putrefactive changes of many bodies, but in the ſwelling they cauſe in oak, and other ſolid wood; as appears by the difficulty we often find in, and before, rainy weather, to ſhut and open doors, boxes, and other pieces of wood-work, that were, before, fit enough for the cavities whereto they had been adjuſted. The ſtrings of viols, and other muſical inſtruments, are ſometimes ſtrong enough to ſuſtain conſiderable weights; yet, if left ſcrew'd to their full tenſion, they are often broken by the moiſt weather, with great impetuoſity and noiſe.

To try what a number of aqueous ſteams might do, I caus'd a long ſlender rope, which was, in part, ſuſtain'd by a pully, to have a weight of lead ſo faſten'd to the end of it, as not to touch the ground; and after the weight had leiſure allow'd it to ſtretch to the cord, as far as it cou'd, I obſerv'd, that, in moiſt weather, the watry particles, that inviſibly abounded in the air, ſo affected and ſhorten'd the rope, as to make it lift up the weight, which was about an hundred pounds.

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PHYSICS. The inviſible ſteams iſſuing out of the walls of a newly plaiſter'd room, wherein there is a charcoal fire, are not ſenſibly prejudicial to thoſe who make but a ſhort ſtay therein; but we have many inſtances of perſons, who lying for a night in ſuch rooms, have been found dead in their beds, the next morning; being ſuffocated by the multitude of noxious vapours emitted, during that time.

'Tis proper to obſerve, that effluvia are not emitted from bodies, all at once, as ſhot is from a gun; but iſſue from it, as the vapours out of a well-heated æolipile, or waters out of a ſpring-head, *in continued* ſtreams, wherein freſh parts ſtill ſucceed; ſo that tho' as many effluvia of a body, as can be ſent out at one time, were numerous enough to act but upon the ſuperficial parts, yet the efflux of the next minute may get in a little farther; and each ſmalleſt portion of time admitting of freſh recruits, whilſt, perhaps, the ſteams already enter'd are urg'd on, the particles may, at length, get into a multitude of the pores, and penetrate to the very innermoſt parts of the body.

Some Effluvia very ſubtile and penetrating.

That the ſubtile and penetrating nature of effluvia, may, in many caſes, co-operate with their multitude, in producing notable effects; and that there are effluvia of a very piercing nature, will appear from ſeveral examples. For, not only the inviſible ſteams of good *Aqua fortis*, and ſpirit of nitre uſually, in a ſhort time, and, in the cold, ſo penetrate the corks, wherewith the containing glaſſes were ſtopp'd, as to reduce them to a yellow pulp; but alſo exhalations of mercury have been, ſometimes, found in the form of coagulated, or even of running mercury, in the heads, or very bodies of thoſe gilders, or venereal patients, who have been too long, or too raſhly, expoſed to the fumes of it; tho' they never took quick-ſilver in its groſs ſubſtance. Chymiſts too often find in their laboratories, that the ſteams of ſulphur, antimony, arſenic, *&c.* are able to make thoſe ſtagger, or, perhaps, ſtrike them down, who careleſly unlute the veſſels wherein they had been diſtill'd or ſublim'd; of which I have known many ſad examples.

And, of the penetracy even of animal ſteams, we may eaſily be perſwaded, if we conſider how ſoon, in many plagues, the contiguous, but *inviſible* exhalations are able to reach the heart, or infect other internal parts; for tho', in many of theſe caſes, the blood helps to convey the infection, yet ſtill the morbific particles muſt get into the body, before they can infect the maſs of blood. And in thoſe ſtupefactions, caus'd, at a diſtance, by the torpedo, the parts principally affected, ſeem to be the nervous ones of the hand and arm, which are of the moſt retired, and beſt-fenced parts of thoſe members. And I make the ſpirit of ſal-armoniac, whoſe inviſible ſteams, unexcited by heat, are of ſo piercing a nature, as ſtrongly to affect the eyes, and noſtrils, and throats, and ſometimes the ſtomachs too, of thoſe they invade; and when a great cold has ſo clogg'd the organs of ſmelling, that neither ſweet nor fetid odours wou'd at all affect them; theſe piercing ſteams have not only, in a few minutes, made themſelves way, but ſo open'd the paſſages, that ſoon after, the patient has

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has been able to ſmell other things alſo. And, by the ſame penetrating ſpirit, a perſon of quality was reſtored to the faculty of ſmelling, which he had loſt for ſeveral years. Nay, the ſteams of water itſelf, aſſiſted by warmth, are able to diſſolve the texture even of hard and ſolid bodies, that are not ſuſpected to be ſaline; as appears by the philoſophical calcination, wherein ſolid pieces of harts-horn are brought to be eaſily crumbled into powder, by being hung over water, whilſt its ſteam riſes in diſtillation, and without the help of furnaces. The exhalations that uſually ſwim every night in the air, and almoſt every night fall to the ground in form of dews, are, in many places of the torrid zone, of ſo penetrating a nature, that, as eye-witneſſes have informed me, they wou'd in a very ſhort time, make knives ruſt in their ſheaths, ſwords in their ſcabbards, and watches in their caſes, if not conſtantly carried in the pocket. And I have known, even in *England*, ſeveral hard bodies into which the vapours, floating in the air, have inſinuated themſelves ſo far, as to make them friable throughout. Physics

But to ſhew that the penetrancy and the multitude of effluvia may greatly aſſiſt each other, we muſt not uſually look upon effluvia as ſwarms of corpuſcles, that only beat againſt the outſides of the bodies they invade; but as particles, which, by reaſon of their great, and frequently recruited numbers, and by their extreme ſmallneſs of parts, inſinuate themſelves, in multitudes, into the minute pores of the bodies they invade, and often penetrate to the innermoſt of 'em; ſo that, tho' each ſingle corpuſcle and its diſtinct action be inconſiderable, in reſpect of the multitude of parts that compoſe the body to be wrought on; yet a vaſt number of theſe little agents, working together upon a correſpondent number of the ſmall parts of the body, they may well have powerful effects upon it. Thus the rope, before-mention'd, would not, probably, have been enabled to raiſe ſo great a weight, tho' a vehement wind had blown againſt it, to make it loſe its perpendicular ſtraitneſs; but a vaſt multitude of watery particles getting by degrees into its pores, might, like an innumerable company of little wedges, ſo widen them, as to make the hempen threads ſwell ſo forcibly, that the depending weight cou'd not hinder the ſhortening of the rope. I have, more than once, known ſolid, and even heavy mineral bodies burſt in pieces by the moiſture of the air; tho' we kept them, within doors, carefully ſhelter'd from the rain. *Eſpecially, when they act in ſwarms.*

That the celerity of the motion of numberleſs very minute bodies will have very great effects, may be argued from the wonderful phenomena of fired gun-powder, *Aurum fulminans*, flames that inviſibly touch the bodies they work on, whirl-winds, and thoſe ſtreams of inviſible exhalations, and other aerial particles we call winds. That the corpuſcles whereof odours conſiſt, ſwim about the air, as in a fluid vehicle, may be eaſily prov'd. But the motion of the effluvia of ſome ſufficiently odorous bodies, has too little celerity to make a ſenſible impreſſion on the organs of ſmelling, unleſs the ſteams be aſſiſted to beat more forcibly upon the noſtrils by the air, which hurries them along with it, when it ſtreams into their ca- *And with great velocity.*

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PHYSICS. vities in the act of inspiration. Thus we see, when the nostrils of setting-dogs are turn'd to the wind, the current of the air drives the scent of the game, more forcibly, upon the organ.

That a briskness of motion is requisite, and greatly conducive to electrical attractions, appears from the necessity we usually find by rubbing amber, jet, &c. to make them emit those steams, by which, 'tis highly probable, their action is perform'd; and this attrition, I conceive, makes a reciprocal motion amongst the more stable parts, and thereby, as 'twere, discharges and shoots out the attracting corpuscles. That these are actually emitted, appears from an observation I long since made; which was, that if when we took a vigorously excited electric, we did, at a certain juncture of time, place it at a just distance from a suspended hair, or other light body; the hair, &c. wou'd not be attracted to the electric, but be driven away from it, as it seem'd by the brisk steams that issued out of the electric body.

There is a certain substance, which, being made by distillation in the cold, emits only a very mild and inoffensive smell; but when the vessel, that contains it is heated, tho' no separation of constituent principles appears to be thereby made, the effluvia will be so alter'd, that one, who, to satisfy his curiosity, wou'd needs be smelling to it, when 'twas heated, declared, he thought the steams wou'd have kill'd him; and that the effluvia of spirit of sal-armoniac were nothing near so piercing as these.

Other modifications of motion may give vigour to effluvia.

And among solid bodies, there are some, which, tho' abounding much in a substance wherein rank smells principally reside, yet are scarce, at all, sensibly odorous; but, upon rubbing of them a little, one against the other, so dart out their emissions, as in a minute or two, to make a very offensive smell.

And, as the celerity of motion may thus give us vigour to the exhalations of bodies; so there may be other modifications of motion that contribute to the same thing. For not only greater bodies operate differently, according to particular modifications; but even in small particles themselves, it cannot be all one, as to their effects, whether they move with or without rotation, whether in such a particular line, whether with or without undulation, trembling, or such a kind of consecution; and, in short, whether the motion have, or have not, this or that particular modification; which, how much it may diversify the effects of the bodies moved, appears by the motion, that the aerial particles are put into, by musical instruments. For, tho' the effects of harmony, discord, and peculiar sounds, be sometimes very great, not only in human bodies, but in such as are inorganical; the whole efficacy of music and of sounds, that are not extraordinary loud and different, seems to depend upon the different manners of motion whereinto that air is put, which makes the immediate impressions on our organs of hearing.

Odd effects of lightning.

As for celerity, and other modes that diversify the motion of effluvia, I shall only, in this place, take notice of those effects of lightning, which seem

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ſeem referable to the celerity, manner of a pulſe, to the diſtinct ſizes and ſhapes of the corpuſcles that compoſe the deſtructive matter, and to the peculiar relation between the particles of that matter, and the ſtructure of bodies they invade. Many ſtrange things reported, as the effects of what the *Latins* call *fulmen*, are merely fabulous; but others are not ſo: ſome of which I have been an eye-witneſs of, within leſs than a quarter of an hour after the thing has happen'd. And tho' it be very difficult to explain, particularly, many of theſe true phenomena; yet it ſeems warrantable enough to argue from them, that there may be agents ſo qualified, and ſo ſwiftly mov'd, that, notwithſtanding they are ſo exceedingly minute, as is neceſſary to make up a flame which is a fluid body, they muſt, in an imperceptible point of time, pervade ſolid bodies; and traverſing ſome of them, without violating their texture, burn, break, melt, and produce other very great changes, in bodies, that are fitted to be wrought on by them. I was once ſhewn, as a great curioſity, a fine pair of drinking-glaſſes, ſomewhat ſlender, but very tall, which ſeem'd deſign'd to reſemble one another: but, before I ſaw them, the reſemblance was much leſſen'd by the lightning which fell between them, in ſo ſtrange a manner, without breaking either, that I cou'd perceive it had a little alter'd the figure of one of them, near the lower part of the cavity; but the other was ſo bent, near the ſame place, as to make it ſtand quite awry, in a ſurprizing poſture. It alſo appears ſtrange to me, that nature ſhou'd, in the free air, make of perhaps inviſible exhalations, ſuch an aggregate of corpuſcles, as, without breaking the frail body of the glaſſes, had a power, in its paſſage thro' them, that is, in the twinkling of an eye, to melt them; which, even in our reverberatory furnaces, wou'd require a conſiderable time to do.

Upon hearing a clap of thunder, ſo near at hand, that I judg'd ſome of the neighbouring places to be ſtruck; I ſent preſently to make inquiry, and immediately repair'd to the houſe where the miſchief was done, by ſomething, which, thoſe, who pretended to have ſeen it coming thither, affirm'd to be like a flame, moved very obliquely. But obſerving narrowly what had happen'd in an upper room, where it firſt fell, I ſaw that it had, in more than one place, melted the lead in its paſſage, without breaking the glaſs caſements, or burning the bed, hangings, or any other combuſtible goods, tho', near the window, it had thrown down a large part of a wall, through which it ſeem'd to have made its paſſage in or out. And having curiouſly pry'd into the effects of the *fulmen*, in other places of the houſe beneath, in whoſe loweſt parts it ſeem'd to have ended its courſe; I cou'd not but conclude, that, if it were the ſame *fulmen*, it muſt, more than once, have gone in and out of the houſe; and that the line of its motion was not reducible to any curve or mix'd line I had met with; but that it moved to and fro, in an irregular manner, not unlike the wrigling of fire-ſquibs. I ſhall only add, 'tis a known tradition, which my own obſervations heedfully made ſeem, now and then, to confirm, that vehement thunder, if beer be not very ſtrong, will uſually turn it

And thunder.

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PHYSICS. it four in a day or two's time. Now, if this degeneration be not one of the consequences of the great and peculiar kinds of the concuſſions of the air that happen in loud thunder, the effect may probably be aſcribed to ſome ſubtile exhalations diffus'd thro' the air, which, penetrating the pores of the wood, in veſſels whoſe contexture is not very cloſe, embue the liquor with a kind of acetous ferment. For, conſidering that the pores of glaſs are ſo cloſe, as to be impervious to the ſteams, or ſpirituous parts of ſulphur, as well as to other odorous exhalations; I thought it worth trying, whether there be any ſulphureous ſteams, or other corpuſcles diffuſed *thro' the* air, in the time of thunder, that wou'd not be too groſs to get in at ſuch minute pores as thoſe of glaſs. And, accordingly, having hermetically ſeal'd up both beer and ale apart, I kept them, in the ſummer-time, till there happen'd a great thunder, for a day or two; after which, the beer that we, in common, drank, which was good before, being generally complain'd of, as turn'd ſour by the thunder, I ſuffer'd my liquors to continue at leaſt a day or two longer, that the ſouring ſteams, if any ſuch there were, might have time enough to operate upon them; and then, breaking the glaſſes, found the liquors good, tho' we had purpoſely forborn the filling the glaſſes, to facilitate the degeneration. The method of preventing the ill effects of thunder upon barrel'd liquors, if it conſtantly ſucceed, deſerves alſo to be here conſider'd. This method conſiſts in placeing a chafing-diſh of live coals, at a convenient diſtance under the barrels, when the thunder ſeems likely to begin.

Effluvia may produce great effects, by exciting a communicative motion in bodies.

The fifth way wherein effluvia may have conſiderable effects, is the motion of one part upon another, that they may excite or occaſion in the body they work on, according to its ſtructure. But I here propoſe to ſhew their efficacy upon this account, only on organical and living bodies: tho' even inanimate and ſolid bodies may be of ſuch a ſtructure, as to receive great alterations from the appropriated effluvia of others; as may be inſtanced in the power, that I have known, of ſome vigorous load-ſtones to take away, in a trice, the attractive virtue of an excited needle, or giving a verticity, directly contrary to the former, without ſo much as touching it.

The load-ſtone, alſo, affords an eminent example of the great power of a multitude of viſible effluvia from ſmall bodies, upon ſuch as are inorganical or lifeleſs; for ſuppoſing magnetiſm to be performed by corporeal emiſſions, we may conſider, that theſe paſſing unreſiſted, through the pores of all ſolid bodies, and even glaſs itſelf; which neither the moſt ſubtile odours, nor electrical exhalations are obſerv'd to do; ſeem to be almoſt incredibly minute, and much ſmaller than any other effluvia, tho' thoſe are inviſible; yet ſuch incomparably little magnetical ſteams, proceeding from vigorous load-ſtones, will be able to make up conſiderable quantities of ſo ponderous a body as iron *. And I have ſeen a load-

* An experiment made by Mr. *Hauksbee*, wherein the attrition of one glaſs body, produces a continued light on another, at a diſtance from it, ſhews, that effluvia, acting with force and vigour, may perform the office of ſolid bodies. See *Hauksb. Experim.* p. 79——86.

ſtone,

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ſtone, not very large, which wou'd keep a weight of iron ſuſpended, that I could hardly raiſe with one arm; and another little one, with which I cou'd take up above 80 times its own weight. And theſe effluvia do not only, for a moment, faſten the iron to the ſtone, but keep it ſuſpended, as long as one pleaſes. PHYSICS.

But the chief effects of effluvia, here to be conſidered, are produced upon animals, which by virtue of their curious and elaborate ſtructure, have their parts ſo connected, and otherwiſe contriv'd, that the motions or changes made in one, may have, by the conſent of parts, a manifeſt operation upon others, tho', perhaps, very diſtant from it. *Particularly in thoſe of men.*

And, firſt, 'tis plain, that our organs of ſmelling are ſenſibly affected by ſuch minute particles of matter, as the fineſt odours conſiſt of. Nor do they always affect us preciſely, as odours, ſince many perſons, both men and women, are by ſmells, either ſweet or fetid, put into troubleſome head-aches. If it were not ordinary, it would ſeem incredible, that the ſcent of a pleaſing perfume ſhou'd preſently produce in a human body, that immediately before was well and ſtrong, ſuch faintneſs, ſwoonings, loſs of ſenſible reſpiration, intumeſcence of the abdomen, convulſive motions of the limbs, and many other frightful ſymptoms, that by the unſkilful are often taken for the effects of witchcraft, and wou'd impoſe upon phyſicians themſelves, if experience did not furniſh them with examples of the like phenomena, produced by natural means. Theſe ſymptoms manifeſt what the conſent of parts may do in a human body; ſince even morbific odours, by immediately affecting the organs of ſmelling, affect ſo many other parts of the *Genus nervoſum*, as oftentimes to produce convulſions in the extreme parts of the hands and feet.

But the efficacy of effluvia is not confined to produce hyſterical fits: theſe inviſible particles may be able ſuddenly to appeaſe them; as have very frequently try'd, by holding the ſpirit of ſal-armoniac under the noſtrils of perſons thus affected.

I attribute the operations of theſe ſteams rather, in general, to the conſent of the parts that make up the *Genus nervoſum*, than to any hidden ſympathy or antipathy, betwixt them and the womb; becauſe I have known odours produce conſiderable effects upon men. I am acquainted with a gentleman of a ſtrong conſtitution, but conſiderably ſanguine, who is put into violent head-aches by the ſmell of muſk. And I, being one day with him, and a great many other perſons of note, about a public affair; a man, who had a parcel of muſk about him, making application to us, this gentlemam was ſo diſorder'd by the ſmell of it, which to moſt of us prov'd delightful, that he was reduced to make us an apology, and ſend the perfum'd man out of the room; notwithſtanding which, he for a conſiderable time after, complain'd to me, of a violent pain in his head, which, I perceiv'd, had unfitted him for the tranſaction of the affair, whereof he was to be the chief manager. I knew another perſon, who is ſubject to the head-ach upon ſo mild a ſmell as that of damaſk roſes, and, ſometimes, even of red roſes; ſo that walking one day with him in

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PHYSICS. a garden, tho' the alleys were very large, ſo that he might eaſily keep himſelf at a diſtance from the roſe-buſhes; he abruptly broke off the diſcourſe we were engaged in, complain'd of the offence the perfume gave to his head, and deſir'd me to paſs into a walk, that had no roſes growing near it. I alſo know a diſcreet lady, to whom the ſmell of roſes is not unpleaſing, but ſo hurtful, that it preſently makes her ſick, and wou'd make her ſwoon, if not ſeaſonably prevented.

And, as odours may thus give men the head-ach, ſo I have often found the rectified ſpirit of ſal-armoniac, to free both men and women from the fits of that diſtemper; and ſometimes, all of a ſudden. And tho' I have not always found ſo ſlight a remedy to work the deſir'd cure, yet that doing it often, even in men, is ſufficient to ſhew the efficacy of medicinal effluvia.

'Tis a known thing, that women with child have been often made to miſcarry, by the ſmell of an ill extinguiſhed candle; tho', perhaps, the ſmoke, aſcending from the ſnuff, was diſſipated into inviſible corpuſcles, long before it arriv'd at the noſtrils of the women: and what violent motions, abortions are frequently accompanied with, I need not ſay.

I am acquainted with a phyſician, who, having for a long time, when young, been compell'd to take lenitive electuary, one of the gentleſt and moſt pleaſant laxatives of the ſhops, conceiv'd ſuch a diſlike of it, that ſtill, as himſelf aſſures me, if he ſmell to it, it will work both upwards and downwards with him. Another very ingenious perſon, of the ſame faculty, has complain'd to me, that the ſmell of the greaſe, uſed to the wheels of a hackney-coach, tho' the coach do but paſs by him, makes him ready to vomit.

Every body knows, that ſmoke is apt to make men's eyes water, and excite in the organs of reſpiration, that vehement commotion, call'd coughing. But we need not have recourſe to viſible fumes for the production of the like effects; ſince we have often obſerv'd them, together with repeated ſneezings, to proceed from the inviſible ſteams of ſpirit of ſal-armoniac, when only ſmall vials, containing that liquor, were put too near, or too haſtily to the noſtrils. In the foregoing inſtances, the chief effects ſeem to be produced by the conſent of parts on the *Genus nervoſum*, and the action of one of them upon the other; but the following is of a mild and grateful odour, upon the humours themſelves.

A famous apothecary, who is a very tall luſty man, ſeveral times told me, that tho' he was once a great lover of roſes; yet, having occaſion to employ great quantities of them, at a time, their ſteams have ſo alter'd him, that, if he now comes among the roſe-buſhes, the ſmell greatly diſcompoſes him. And the odour of damask-roſes, produces ſuch a flux of humours in his head, that it ſets him a coughing, running at the noſe, gives him a ſore throat, and makes his eyes ſore; ſo that during the ſeaſon of roſes, when quantities of them are brought to his houſe, he is generally oblig'd to be abſent.

And

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And as effluvia thus cauſe one part of a living engine to work upon another, by virtue of its ſtructure, ſo the action of ſuch inviſible agents, may, often, be much promoted by the fabric, and laws of the univerſe itſelf; for by operating upon particular bodies, they may diſpoſe, and, now, firſt qualify them to be wrought upon by light, magnetiſm, the atmoſphere, gravity, or ſome other of the more univerſal agents of nature. PHYSICS.

SECT. III.

The determinate nature of effluvia.

THE effluvia of bodies being, for the moſt part, inviſible, they have been very little conſider'd, by vulgar philoſophers; who ſcarce taking notice of their exiſtence, 'tis no wonder that their diſtinct natures and differences, ſhould be unknown. *Ariſtotle* and the ſchools imagine, indeed, that the two grand parts of our globe do, ſometimes, emit two kinds of exhalations or ſteams: the earth affording thoſe that are hot and dry, which they name fumes, and very often, ſimply, exhalations; and the water others that are hot and moiſt, which they, uſually, call vapours, to diſtinguiſh them from fumes; tho', otherwiſe, theſe appellations are frequently confounded.

That effluvia may retain the nature of the ſubſtances which yield them.

But, beſides ſuch ſlight and obvious differences, the ſteams of bodies may be almoſt as various as the bodies themſelves; and, therefore, we ought not to look upon them, barely, under the general and confuſed notion of ſmoke or vapours; for they may probably have their diſtinct and determinate natures, ſuitable to that of the ſubſtance from whence they proceed.

Illuſtrated.

Now, conſidering that fluid bodies may be of very unequal denſity and gravity, as is evident in quick-ſilver, water, and ſpirit of wine; and yet agree in the conditions requiſite to fluidity; I preſum'd, by that I cou'd make viſible in one, what happens, analogically, in the other, might be ocularly illuſtrated. I, therefore, took ſome ounces of roch-alum, and as much of fine ſalt-peter: theſe being diſſolv'd together, in fair water, the filter'd ſolution was ſet to evaporate, in an open-mouth'd glaſs, and afterwards left to ſhoot, in a cool place, when there faſten'd to the ſides of the glaſs, ſeveral ſmall cryſtals, ſome eight-ſided, which is the figure proper to roch-alum, and others of the priſmatical ſhape of pure ſalt-peter; beſides other ſaline concretions, of neither of theſe two ſhapes, diſtinctly; which argued them to be concoagulations of both the ſalts. And this we did, by uſing ſuch a degree of celerity, in evaporating the liquor, as was proper for ſuch an effect. For, by another degree, which is to be employ'd to recover the ſalts more diſtinctly and manifeſtly, the matter may be ſo order'd, that the aluminous ſalt ſhall, for the moſt part, be firſt

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PHYSICS. coagulated by itself; and then, from the remaining liquor, curiously shap'd crystals of nitre be plentifully obtain'd.

Trials, like this, we also made with other salts, and, particularly, with sea-salt, with alum, and with vitriol. But the present experiment will, alone, assist the imagination to conceive, how the particles of bodies may swim about in a fluid; and, tho' small enough to be invisible, many of them retain their distinct and determinate natures, and their aptness to cohere, upon occasion; as others may, by their various occursions and coalitions, unite into less corpuscles, or greater bodies, different from the more simple particles that compose them; and yet not prove of indeterminate, tho' compounded figures.

And proved by examples of their re-union.

And now we may proceed to particular instances of the determinate nature of effluvia. In the first place then, that the effluvia of many bodies, often, retain a determinate nature, in an invisible smallness, and, oftner, in such a size, as renders them little enough to fly or swim in the air, may appear from hence, that these effluvia being, by condensation, or otherwise, re-united, they prove of the same nature with the body that emitted them. Thus, in moist weather, the vapours of water, that wander invisibly thro' the air, meeting with marble pillars, pavements, &c. by their coldness, and other qualifications, fit to condense and retain them, appear again, in the form of drops of water; and the same vapours return to the visible form of water, when they fall out of the air in dews, or rains.

Quick-silver itself, if made to ascend in distillation, with a convenient degree of fire, will, almost wholly, come over, in the form of running mercury; which strange and penetrating fluid, is, in some cases, so disposed to be stripp'd of its disguizes, and appear again in its own form, that many artificers, and, especially gilders, will tell us, that the fumes of it need not be, as in distillation, included in close vessels, to return to their pristine nature; real mercury having been, several times, found in the heads, and other parts of those, who have dealt much in it. And, 'tis a common practice, both among gilders, and some chymists, when they have occasion to make an amalgam, or force away the mercury from one, by the fire, to keep gold in their mouths, which by the mercurial fumes, that wander through the air, will, now and then, by that time 'tis taken out, be turn'd almost white, as if it had been silver'd over. A mass of purified brimstone being sublim'd, the ascending fumes will condense into what the chymists call *Flores sulphuris*, which is true sulphur, of the same nature with that formerly expos'd to sublimation; and may, readily, by melting, be reduced into such another mass. And, by subliming good camphire, in close vessels, I found it wou'd all, as to sense, be rais'd into the upper vessel, in the form of dry camphire, as it was before. Nay, tho' a body be not by nature, but by art, compounded of such different substances as a metal, and another mineral, and two or three salts; yet if, upon purification of the mixture, from its grosser parts, the remaining and finer parts be minute enough, and fitly shap'd, the whole

whole liquor will aſcend; yet, in the receiver, altogether recover its priſtine form of a tranſparent fluid, compos'd of different ſaline and mineral parts. This is evident in the diſtillation of what chymiſts call butter or oil of antimony very well rectified. For that liquor will paſs into the receiver, tranſparent and fluid, tho', beſides the particles of the ſublimate, it abounds with antimonial corpuſcles, carried over and kept inviſible by the corroding ſalts. I found too, by enquiring of one who had an intereſt in a tin-mine, than tin itſelf, tho' a metal, whoſe ore is of a difficult fuſion, and which I have, by itſelf, kept long upon the cupel, without perceiving it to fly away, would yet retain its metalline nature, in the form of fumes, or flowers. And I have myſelf, more than once, rais'd this metal in the form of white corpuſcles, by the help of half its quantity of an addition. Fumes.

By others, of the difference obſervable in their ſenſible qualities.

A ſecond way, whereby we may diſcover the terminate nature of effluvia, is, from the difference, ſometimes, obſervable in their ſenſible qualities. For, tho' the effluvia that are endow'd with them, proceed the ſame ſort of bodies; yet thoſe afforded by one body, being, in many caſes, manifeſtly different from what fly off from another, argues their retaining diſtinct natures, according to thoſe of the reſpective bodies whence they proceed.

I will not examine, whether in the ſteams made, viſibly, to aſcend from the terreſtrial globe by the ſun, and the agitation of the air, the eye can manifeſtly diſtinguiſh a diverſity of colours; but of ſome productions of art, ſuch different colours may be diſcovered in the exhalations, even without the application of any external heat to raiſe them. Thus, when ſpirit of nitre, for example, has been well rectify'd, I have often obſerv'd, that even in the cold, the fumes wou'd play in the unfill'd part of the ſtopp'd vial it was kept in, and appear of a reddiſh colour; and if the veſſel were open'd, the ſame fumes would plentifully aſcend into the air, in the form of a reddiſh or orange-tawny ſmoak. Spirit, or oil of ſalt, alſo, if it be well rectify'd, tho' it will ſcarce, in the cold, viſibly aſcend in the empty part of a vial, whilſt kept well ſtopp'd; yet if the air be allow'd free acceſs to it, will fly up in the form of a whitiſh fume. But this is inconſiderable, in compariſon of what happens in a volatile tincture of ſulphur, made with quick-lime; for, not only upon a ſlight occaſion, the vacant part of the vial will be fill'd with white fumes, tho' the glaſs is well ſtopp'd, but, upon opening the vial, theſe fumes will largely paſs out at the neck, and aſcend into the air, in the form of an exceeding white ſmoak. And both this, and the ſpirit of nitre, by their operations, as well as ſmell, diſcover what they are; ſo that having, in a fitly-ſhap'd glaſs, caught a competent quantity of the aſcending white fumes, I found them to have conven'd into bodies tranſparent, and geometrically figur'd; wherein 'twas eaſy to obſerve, from their ſenſible qualities, that there were numerous ſulphureous particles mixed with the ſaline ones. That the liquors of vegetables, diſtill'd *in balneo*, or in water, uſually retain nothing of the colour of the bodies that afforded them,

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PHYSICS. them, is obvious, in diſtillations made without retorts, or a violent fire: but it may be worth while to try, whether the eſſential oil of wormwood aſcend colour'd, like the plant, when 'tis firſt drawn over with water in the limbec, or rectified *in balneo*. In a firſt diſtillation of this plant, in a copper limbec tinn'd on the inſide, I once found the oil came over green, and was not, by a rectification, purpoſely made in a glaſs veſſel, depriv'd of that colour.

And tho' eſſential oils be but effluvia of the vegetables they are diſtill'd from, condens'd, in the receiver, into liquors; yet, notwithſtanding their ſubtilty, many of 'em retain the genuine taſte of the bodies whence the heat elevates them. And wormwood is a plant, whoſe effluvia ſo retain the nature of the body, from whence they proceed, that coming into a room, where a quantity of it was kept, not only the organs of ſmelling were, powerfully, ſtruck by the corpuſcles which ſwarm'd in the air; but alſo the mouth was ſenſibly affected with a bitter taſte. And I have found the expirations of amber, kept a while in pure ſpirit of wine, taſte upon the tongue like amber itſelf, when chew'd between the teeth. But the expirations I have obtain'd from amber, both with pure ſpirit of wine, and a more piercing menſtruum, manifeſtly retain'd the peculiar ſmell wherewith that ſubſtance affects the noſtrils, when its electrical faculty is excited by rubbing. And, as for odours, 'tis plain, that the eſſential oils, well drawn, do many of them retain the peculiar and genuine ſcent of the ſpices, or herbs, that afford them. And that theſe odours really conſiſt of, or reſide in, certain inviſible corpuſcles flying off from the viſible bodies, ſaid to be of ſuch ſmells, may ſufficiently appear from their ſticking to many of the bodies they meet with, and their laſting adheſion to them.

Which would be more obvious, if the human ſenſes were more acute.

Other examples may be given of the ſettled difference of effluvia, directly perceivable by human organs of ſenſe; but I ſcarce doubt, if our organs were extremely tender, that they might, immediately, perceive in the fize, ſhape, motion, and, perhaps, colour too, of ſome effluvia, which are now inviſible, as diſtinguiſhable differences, as our naked eyes, in their preſent conſtitution, ſee between the different ſorts of birds, by their appearance and manner of flight. In fine, white ſand, whoſe grains, to the naked eye, are not, uſually, diſtinguiſh'd by any ſenſible quality, I have, often, obſerv'd, thro' an excellent microſcope, a notable diſparity, as to bulk, figure, and ſometimes colour. Nay, I have, ſometimes, ſeen a very evident diſparity, even in point of ſhape, between the eggs of cheeſe-mites. And tho' the touch is reckon'd one of the moſt dull of the five ſenſes, and reputed far leſs quick in man, than in ſeveral other animals: yet the groſs organs hereof, even in men, may, by accident, be ſo diſpos'd, as to be ſuſceptible of impreſſions from effluvia: and, perhaps, ſeveral of the preſages of weather, obſervable in ſome animals, and the aches and other pains that, in many crazy and wounded men, uſually precede great changes of weather, often proceed from inviſible effluvia, which, either from the ſubterraneal parts, or from ſome bodies

bodies above ground, plentifully impregnate the air. *Diemerbroeck* tells us of himself, that having been infected with the plague, he was, by the application of a seasonable remedy, quickly cured, without the breaking of any tumour; yet it left such a change in some parts of his body, that when he, afterwards, visited such as were infected with that distemper, he felt a pain in the emunctories, which advertis'd him, that the distemper was the plague. PHYSICS.

And an ingenious gentlewoman, of a very curious and delicate complexion, has several times assur'd me, that she can, very readily, discover, whether, a person, who visits her in the winter, came from a place where there is any considerable quantity of snow; and this she does, not by feeling any unusual cold, but from some peculiar impression, which, she thinks, she receives by the organs of smelling. I might add, that I knew, also, a very ingenious physician, who, falling into an odd kind of fever, had his sense of hearing thereby render'd so very nice and tender, that he very plainly heard soft whispers, made at a considerable distance, which were not in the least perceiv'd by the healthy by-standers; nor would have been by him, before his sickness: but when the fever had quite left him, he heard but as other men. I likewise, know a gentleman, who, during a distemper in his eyes, had his organs of sight brought to be so tender, that both himself, and his friends, have assur'd me, when he awak'd, in the night, he cou'd, for a while, plainly see, and distinguish colours, and other visible objects; as was, more than once, try'd, by pinning ribbands, or the like bodies, of several colours, to the inside of his curtains, in the dark.

Some effluvia affect not men, but other creatures.

But there are effluvia which affect other creatures, tho' they make no impressions on men. A person of quality, to whom I am near allied, assured me, that, to try whether a young blood-hound was well made, he caus'd one of his servants, who had not kill'd, or touch'd, any of his deer, to walk to a country-town, four miles off, and then to a market-town three miles distant from that; which done, this nobleman, a competent while after, put the blood-hound upon the scent of the man, and caus'd him to be follow'd by a servant or two; the master himself going after, to know the event; which was, that the dog, without ever seeing the man he was to pursue, followed him, by the scent, to the above-mention'd places, notwithstanding the multitude of market-people who went along in the same way, and of travellers, who had occasion to cross it: and when the blood-hound came to the chief market-town, he pass'd thro' the streets, without taking notice of any of the people there, and left not till he had gone to the house, where the man, he sought for, rested himself; and found him in an upper room. An ingenious gentleman assur'd me, he had dogs, of so good a scent, that if a buck pass'd in a wood, on one day, they will, on the next, when they come near where the scent lies, tho' at such a distance of time, presently find it, and run, directly, to that part of the wood where the buck is.

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PHYSICA. He also told me, that tho' an old blood-hound will not so easily fix on the scent of a single deer, that presently hides himself in a whole herd; yet, if the deer be chas'd a little, till he is heated, the dog will go nigh to single him out. The same gentleman farther affirmed, that he could easily distinguish, whether his hounds were in chase of a hare or a fox, by their way of running, and holding their noses higher than ordinary, when they pursue a fox, whose scent is stronger. These relations will not be judg'd incredible by him, who, reflects on some of the instances we have produced, of the strange subtilty of effluvia. And to try whether I cou'd, in some measure, by art, imitate nature, I prepar'd a body, of a vegetable substance; which, tho' it were, actually, cold, and seem'd dry, both to the eye and touch, for a while emitted such determinate and piercing, tho' invisible exhalations, that, having applied to it a clear metalline plate, for about a minute, I found, tho' there had been no immediate contact between them, having, purposely, interpos'd a piece of paper to hinder it; yet, there was imprinted, on the surface of the plate, a conspicuous stain of that peculiar colour, the body, with whose steams I had imbu'd the vegetable substance, was fitted to give to that mix'd metal. And tho' in some circumstances, instances about blood-hounds have a considerable advantage of this experiment, yet they lose it again in others; for here the emitting body was firm and cold; but the effect produced by the effluvia that guided the dog, was upon the organ of a warm living creature, and such an one, whose organs of smelling are of an extraordinary tender constitution, above those of other animals; and probably the impression was but transient; whereas, in our case, the invisible steams of the vegetable substance, wrought upon a body of so strong and inorganical a texture, as a metal, fenced by being wrapp'd up in paper; and yet these steams invaded it in such numbers, and so considerably, as to make their operation on it, permanently, manifest to the eye; for, coming to look upon the plate three days after, I found the colour yet conspicuous, and not likely to vanish on a sudden.

Hitherto I have argued, from the constant and settled difference of the sensible qualities of effluvia, that they do not, always, lose their distinct natures, when they seem to have lost themselves, by vanishing into air. But it will be alledg'd, that, in many cases, the effluvia of bodies may, in their passage thro' the air, be sensibly alter'd, or affect the organs of sense, otherwise than each kind of them, apart, wou'd do. And, indeed, it seems consistent with experience, that some such cases should be admitted. However, in those I have insisted upon, and many more, such alterations need not hinder, but that effluvia, at their first parting from the bodies whence they proceed, shou'd retain as much of the nature of those bodies, as we have ascrib'd to them? since the subsequent change may, very probably, be deduced from the combinations and coalitions of several steams associating themselves in the air, and acting upon the organs of sense, either conjointly, or, at least so near it,

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it, that the ſenſe cannot perceive their operations diſtinct. Thus, in a muſical inſtrument, if two ſtrings, tun'd to an eighth, be touch'd together, they ſtrike the ear with a ſound that will be judg'd to be but one; tho' each of the trembling ſtrings makes a diſtinct noiſe, and the one vibrates as faſt again as the other. And if, into oil of tartar, *per deliquium*, you drop a due proportion of ſpirit of nitre, and exhale the ſuperfluous moiſture, the acid and alkaline corpuſcles, that were ſo ſmall, as to ſwim invisibly in thoſe liquors, will convene into nitrous concretions, whoſe taſte will be compounded of, but greatly differ from both the taſtes of the acid and tartareous particles; which particles may yet, for the moſt part, by a ſkilfull diſtillation, be divorc'd again. And ſo, if, to a ſtrong ſolution of pot-aſhes, or ſalt of tartar, you put as much ſal-armoniac as there is of either of thoſe fixed ſalts contained in the liquor, you may, beſides a ſubtile urinous ſpirit that will eaſily come over in the diſtillation, obtain a dry *Caput mortuum*, that is almoſt, totally, a compound ſalt, different from either of the ingredients, eſpecially the alkaline, as well in taſte, as in ſome other qualities.

Examples of coalitions, and reſulting changes of ſteams.

I ſhall now add a few inſtances of the coalition and reſulting change of ſteams in the air. 'Tis eaſily obſervable, in a noſegay, where the different flowers happen to be conveniently mix'd, that in the ſmell afforded by it, at a due diſtance, the odour of the particular flowers are not perceiv'd, but the organ is affected by their joint action, which makes on it a confus'd, but delightful impreſſion. And ſo, when in a ball of pomander, or a perfum'd ſkin, muſk, civet, *&c.* are ſkilfully mix'd; the coalition of the diſtinct effluvia of the ingredients, that aſſociate themſelves in their paſſage thro' the air, produce, on the organ, one grateful perfume, reſulting from all thoſe odours. But if you take ſpirit of fermented urine, and ſpirit of wine, both of them weak, and mix them together, they will incorporate, like wine and water, without affording any dry concretions: if you expoſe them, whilſt in a convenient veſſel, but to the mild heat of a bath, or lamp; the aſcending particles will aſſociate themſelves, and adhere to the upper part of the glaſs, in the form of a white tender ſublimate, conſiſting both of urinous and vinous ſpirits, aſſociated into a mixture, which differs from either of the liquors, not only in conſiſtence, taſte, and ſmell, but in ſome conſiderable operations. And if ſpirit of ſalt, and ſpirit of nitre be, by diſtillation, elevated in the form of fumes, ſo as to convene into one liquor, in the receiver; this liquor will readily diſſolve crude gold: tho' neither the ſpirit of nitre alone, nor that of ſalt, would do ſo.

And, to give an ocular proof of the poſſibility of the diſtinctneſs, and ſubſequent commixture of ſteams in the air, I ſhall relate an experiment devis'd for that purpoſe. I took two ſmall vials, the one fill'd with weak ſpirit of ſalt, the other with ſpirit of fermented urine, or of ſal-armoniac, very well rectify'd; theſe vials being unſtopp'd, and placed at ſome diſtance from one another, each liquor afforded its own ſmell, by the invisible ſteams it emitted into the air. But when theſe vials were brought

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PHYSICS. brought very near to each other, tho' not ſo as to touch, their reſpective effluvia, meeting in the air, would act upon one another, and, by their mutual occurſions, become manifeſtly viſible, and appear moving in the air, like a little portion of ſmoak, or miſt; which wou'd quickly ceaſe, if either of the vials were remov'd half a foot, or a foot, from the other. And, what adds to the oddneſs of the phenomenon, I, ſometimes, ſuſpended a drop of the ſpirit of ſalt, at the bottom of a little ſtick of glaſs; and held this drop, in the orifice of a vial, containing ſpirit of ſal-armoniac, and furniſh'd with a ſomewhat long neck; whereby the aſcending urinous particles, tho' inviſible before, plentifully invading the acid ones of the drop, produced a notable ſmoak; which, if the drop were held a little above the neck of the glaſs, would, moſt commonly, fly upwards, to the height of a foot, or half a yard; but, if held ſomewhat deep in the hollow of the neck, a large part of the produced ſmoak would often fall into the cavity of the vial, which was left in great part empty, ſometimes in the form of drops, but uſually in that of a ſlender, winding ſtream, of a white colour, that ſeem'd to flow down, juſt like a liquor, from the depending drop, till it had reach'd the ſpirit of ſal-armoniac; upon whoſe ſurface it would ſpread itſelf, like a miſt.

Whence, probably, meteors, contagious diſeaſes, and their removal. It might here deſerve to be conſider'd, whether theſe coalitions, of different ſorts of ſteams in the air, and the changes of their particular precedent quantities, reſulting thence, may not aſſiſt us to diſcover the cauſes of ſudden clouds and miſts, and ſome other meteorological phenomena; and alſo of ſeveral changes that happen in the air, with regard to the coming in, and ceaſing, either of epidemical or contagious diſeaſes, and, particularly, the plague. For theſe ſeem to depend upon ſome occult temperature, and alterations of the air; which may be greatly impregnated by the different ſubterraneal effluvia, that often aſcend into it with peſtiferous, or other morbifick corpuſcles; ſometimes with others of a contrary nature: and ſometimes too, perhaps, neither the one ſort of ſteams, which may be ſuppos'd to have imbu'd the air, is, in itſelf deſtructive; nor the other ſalutary, but become ſo upon their caſual coalition in the air. The judicious *Diemerbroeck* tells us, he very often obſerved, during the great plague at *Nimmeguen*, that the diſtemper conſtantly happened in ſuch houſes, wherein linen was waſh'd with *Dutch* ſoap; and that always, the ſame day, or the day after, two or three perſons would fall ſick together, in the ſame houſe; they themſelves acknowledging, that the ill ſcent of the ſoapy water, wrought the firſt great change in them. He adds, alſo, that he had the unwelcome experience of this, in his own houſe; where, immediately upon waſhing, moſt of the family were taken ill: but three women fell ſick of the plague on the night following, and died ſoon after. Now tho', perhaps, ſome other cauſe of this odd phenomenon may be devis'd, yet, that which I aſſign, ſeems, at leaſt, a probable one; ſince, as 'tis manifeſt, by daily experience, the ſmell, occaſion'd by the waſhing of foul linen, with the ſoap, commonly us'd in the *Netherlands*,

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produces not the plague; ſo, by our author's obſervation, it appears, either that there were not yet any peſtilential effluvia in the air of thoſe places, which, on occaſion of the waſhing, became infected; or, at leaſt, that, by the addition of the fetid effluvia of the ſoapy water, thoſe morbific particles, that were diſpers'd thro' the air before, had not the power to introduce a malignant conſtitution into it, and to act as truly peſtilential, till they were enabled to do it, by being aſſociated with the ill-ſcented effluvia of the ſoap.

Whether, alſo, ſalutary, and alexipharmic corpuſcles, may not be produced in the air, by coalition, might be very well worth our inquiry; eſpecially, if we had a good hiſtorical account of the yearly ceaſing of the plague at *Grand Cairo*. For, as *Proſper Alpinus*, who practiſed phyſic there, and ſome of my acquaintance, who have been upon the ſpot, inform me, almoſt in the midſt of ſummer, as ſoon as the river begins to riſe, the plague has its malignity ſuddenly check'd, even in thoſe who are already infected; and ſoon after ceaſes: whence, if other circumſtances contradict not, we might gueſs, that this ſtrange phenomenon may be chiefly occaſion'd by ſome nitrous, or other corpuſcles, that accompany the overflowing of the *Nile*; and, by aſſociating themſelves with the noxious effluvia, diſable them from producing their pernicious effects. Mr. *Sandys* takes notice, that about the time of the overflowing of the *Nile*, whoſe abounding with nitre has been obſerv'd, even by the ancients, that there is a certain moiſtening vapour diffus'd thro' the air. "To prove," ſays he, "that the over-"flowing of the *Nile* proceeds from a natural cauſe, this experiment will "ſuffice. Take of the earth of *Egypt*, adjoining to the river, and pre-"ſerve it carefully, that it neither come to be wet, nor waſted; weigh "it daily, and you ſhall find it neither more nor leſs heavy, till the "17th of *June*, at which day it begins to grow more ponderous, and "increaſes with the augmentation of the river; whereby they have an "infallible knowledge of the ſtate of the deluge, proceeding, without "doubt, from the humidity of the air, which having a recourſe thro' "all paſſable places, and mixing therewith, increaſeth the ſame as it in-"creaſeth in moiſture." That theſe ſanative ſteams perform their effects, merely becauſe they are moiſt, I preſume, will ſcarce be pretended; but that they may be of ſuch a nature, as, by their coalition with the morbific corpuſcles, to increaſe their bulk, and alter their figure, or precipitate them out of the air, or clog their agility, or pervert their motions; in a word, deſtroy all, or ſome of thoſe mechanical properties which render'd them peſtilential, and this ſo that there may reſult, from the aſſociation of two ſorts of particles, whereof one was of a highly noxious nature, a harmleſs mixture, might here be made probable from ſeveral conſiderations. Let me add, that having purpoſely made a viſible and laſting ſtain, on a ſolid body, barely by cold effluvia, I did, by the inviſible and cold ſteams of another body, make, in two or three minutes, a viſible change in the colour of that ſtain.

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PHYSICS. That meteors may, ſometimes, be produced, by the occurſions of ſubterraneal effluvia, ſome of them of one determinate nature, and ſome of another, I might ſhew, by various inſtances of the plentiful impregnation of the air, at ſome times, and places, with ſteams of very different natures; and ſuch as are not ſo likely to be attracted by the heat of the ſun, as to be ſent up from the ſubterraneal regions, and ſometimes from minerals themſelves. And tho' the effluvia, ariſing from the bowels of the earth, are ſometimes ill-ſcented, yet, they are not always ſo. And ſulphureous exhalations from cold and aqueous liquors, may be ſhewn to retain their determinate nature in the air, and, accordingly, to act upon ſolid bodies, to whoſe conſtitution they chance to prove proportionate.

The experienc'd *Agricola*, having mention'd, out of ancient hiſtorians, the raining of white and red liquors, which they erroneouſly took for milk and blood, ſubjoins; "This may be the more eaſily credited, becauſe, in "our fathers memory, drops fell from the air, in *Sweden*, which ſtain'd "ſuch clothes as were made of linen, with red croſſes, as if they had been "blood." And 'tis the leſs improbable, that the more agile corpuſcles of ſubterraneal ſalts, ſulphurs, and bitumens may be rais'd into the air, and keep their diſtinct natures in it, if ſo fix'd a body, as common earth *it ſelf*, can be brought to ſwim in that fluid; yet, the ſame *Agricola* aſſures us, that he ſaw rain fall, ſo mix'd with clay, that the ſtreets were every where cover'd with it.

And to ſhew, that, in ſome caſes, the particles even of vegetable bodies, may not ſo ſoon periſh in the air as they diſappear in it, but retain diſtinct natures, at a greater diſtance than one would imagine, from the bodies that plentifully emit them; I ſhall add, than an ingenious gentleman, who went on a conſiderable employment to the *Eaſt-Indies*, acquainted me that, ſailing along the coaſt of *Ceylon*, famous for cinnamon-trees, and well-ſcented gums, the wind, which then chanced to blow from the iſland, brought them a manifeſtly odoriferous air, tho' they kept off, perhaps 20, or 25 miles from the ſhore. Nor ſhould this be thought incredible, becauſe the diffuſion ſeems ſo diſproportionate to that of other bodies diſſolv'd by fluids; as for inſtance, tho' ſalt be an active body, and reſoluble into abundance of minute particles, yet, one part of ſalt will ſcarce be taſted in an hundred parts of water. For, ſenſibly to affect ſo groſs an organ, as that of our taſte, there is uſually required in ſapid particles, a bigneſs far exceeding that which is neceſſary to make bodies fit objects for the ſenſe of ſmelling. Beſides, there is a great difference between the power a body has to impregnate ſo thin and fine a fluid as the air, whoſe parts are rare and lax, and that which it has to impregnate liquors, ſuch as water, or wine, whoſe parts are ſo crowded, as to make it viſible, tangible, and ponderous. And I found, by trial, that one drop of good chymical oil of cinnamon, being duly mix'd, by means of ſugar, with wine, retain'd the determinate taſte of cinnamon, tho' it was diffus'd into near a quart of it: whence I concluded, that, upon the common ſuppoſition, according to which a drop

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drop is reckon'd for a grain, one part of oil had given the ſpecific taſte of the ſpice it was drawn from, to near fourteen thouſand parts of wine. By comparing this experiment with what I noted, about the proportion of ſalt requiſite to communicate a taſte thereof to water, it will eaſily appear, that there may be a very great difference, in point of diffuſiveneſs, between the little particles that make bodies ſapid. I muſt not omit, that, beſides the almoſt innumerable ſapid parts of a ſpicy drop communicated to the wine, it thence diffuſed a vaſt number of odoriferous particles into the air; which both I, and others perceiv'd to be imbu'd with the diſtinct ſcent of cinnamon: and the liquor was able to have render'd it ſpicy for a very long time. PHYSICS.

The third way of determining the nature of effluvia, by their effects on bodies different from the organs of ſenſe.

The third, and laſt way I ſhall mention, to ſhew the determinate nature of effluvia, ariſes from the conſideration of their effects upon other bodies than the organs of our ſenſes. For the effects that certain bodies produce on others by their effluvia, being conſtant and determinate, and often very different from thoſe which other agents, by their emiſſions, work upon the ſame, and other ſubjects; the diſtinct nature of the corpuſcles emitted, may be thence ſufficiently gather'd.

Now, the temporary numbneſs, or ſtupefaction, produced in the foot, by the effluvia of the fiſh, which we formerly took notice of, as mention'd by *Piſo*, manifeſts, that thoſe ſtupefying exhalations retain a peculiar and venomous nature, during their whole paſſage thro' the ſhoe, ſtocking, and ſkin, interpos'd betwixt the fiſh and the nervous part of the foot, benumb'd by it. And tho' there are few other bodies, in the world, minute enough to paſs thro' the pores of glaſs; 'tis apparent, by the experiment of iron, hermetically ſeal'd up in a glaſs-pipe, that the magnetical effluvia of the earth may retain their peculiar nature, in a ſmallneſs that qualifies them to paſs thoſe freely.

That ſeveral bodies, of a venomous nature, may exerciſe ſome ſuch operations upon others, by their effluvia tranſmitted through the air, as they uſually do in their groſs ſubſtance, is a truth whereof there are ſome examples among phyſicians. *Sennertus* obſerves, as a known thing, that apothecaries ſervants have been caſt into profound ſleeps, when, in diſtilling opiate and hypnotic liquors, they have receiv'd in, at their noſtrils, the vapours exhaling from thoſe bodies. 'Tis recorded by the writers on poiſons, that the root and juice of mandrake caſt thoſe who take them, into a deep ſopor, not unlike a lethargy. And tho' the apples of the ſame plant are thought much leſs malignant, yet *Levinus Lemnius* relates, that having laid ſome of them in his ſtudy, he was, by their ſteams, more than once, made ſo ſleepy, that he could hardly recover himſelf; but, the apples being taken away, he regain'd his vigilance and alacrity.

Among all poiſons there is ſcarce any whoſe phenomena, in my opinion, are more ſtrange, than thoſe that proceed from a mad dog; yet, even this poiſon, which ſeems to require corpuſcles of ſo odd and determinate a nature, is recorded, by phyſicians, to have been convey'd

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PHYSICS. by exhalations. *Aretæus* writes, that a man, who was never bit, but only receives the breath of a mad dog, will grow mad; and, we have accounts of animals that become mad, by having eaten of the parts or excrements of thoſe who were mad. So *Cælius Aurelianus* tells us, that ſome have been made to run mad, not by being bitten, but wounded only with the claws of a mad dog; and adds, that a man fell into a hydrophobia, without being bitten, but infected by the ſmell of a mad dog; whereby I underſtand a ſwarm of effluvia, which are, moſt commonly, all, or, at leaſt, ſome of them, odorous. And, tho' *it may ſeem* ſtrange, that the venom of a mad dog ſhould be communicated otherwiſe than by the bite; 'tis the leſs improbable becauſe *Matthæus de Gradibus* names a perſon who prov'd infected many days after having put his hand into the mouth of a mad dog that did not bite him. And *Matthiolus* relates, that he ſaw two who were made mad without any wound, by the bare ſlabber of a mad dog. *Sennertus* affirms it of a painter of his acquaintance, who, when he open'd a box, in which he had long kept included realgar, a noxious mineral, ſometimes uſed by painters, and not unknown to chymiſts; and had unfortunately ſnuff'd in the ſteams of it; that he was ſeiz'd with a giddineſs in his head, and fainting fits; his whole face alſo ſwelling; tho', by taking of antidotes, *he* ſaved his life.

The probability of what I have thus cited, from credible authors, may be ſtrengthened by the following proof of the diſtinct nature of effluvia. A phyſician of my acquaintance, cauſing a large quantity of black hellebore-root to be long pounded in a mortar, moſt of thoſe who were in the room, and, eſpecially, the perſon who powder'd it, were thereby purged, and ſome of them ſtrongly. *Sennertus* affirms, that ſome will be purg'd by the very odour of colocynth. And in the caſes I have alledg'd, exhalations endow'd with occult qualities, (as cathartic medicines are ſuppoſed to be) aſcend into the air, without being forced from the bodies they belong'd to, by any external heat.

And, if I were here to alledge the operations of ſuch effluvia as do not paſs into the air, but operate only by the contact of the external parts of the body, I cou'd give inſtances, not only of the purgative, but the emetic qualities of ſome medicines exerted without being taken in at the mouth, or injected with inſtruments.

There are, alſo, other ſorts of examples than thoſe hitherto mention'd, that argue a determinate nature in the effluvia of ſome bodies emitted into the air. Approved writers tell us, that the ſhadow of a walnut-tree, with the leaves on it, is very hurtful to the head; and ſome inſtances they give us, of great miſchief it has ſometimes done: and tho' this ſhadow is not likely to produce ſuch a bad effect, yet the effluvia of the neighbouring plant may be noxious enough to the head. For I, being not at all prepoſſeſs'd with this opinion, without ſcruple reſorted to the ſhade of walnut-trees, in a hot country; but was, by experience, forced to think it might give others the head-ach, ſince it did to me,

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who am very little ſubject to that diſtemper. Some ingenious travellers into the *Weſt-Indies* affirm, that birds will, there, not only forbear to eat of the fruit of venomous plants and trees, but will not ſo much as light on ſome of them; which nature, probably, inſtructs them, by ſome noxious ſmell, or other particular effluvia, to avoid. And ſome of our navigators give it for a rule, to thoſe who happen to land in unknown iſlands, that they may venture to eat ſuch plants or fruits, which they can perceive the birds to have been pecking at before. *Nicolaus Florentinus* tells us of a certain *Lombard*, who having, in a houſe at *Florence*, burned a great black ſpider, at the flame of a candle, ſo unwarily, that he drew in the ſteams of it at his noſtrils, preſently began to be much diſorder'd, and fell into a fainting fit, and, for the whole night, had his heart much affected; his pulſe being ſo weak, as hardly to be perceiv'd; tho' he was, afterwards, cured by a mixture of *Venice*-treacle *Diamoſchus*, and the powder of zedoary. In *Ireland*, I gather'd a certain plant peculiar to ſome parts of that country, which the natives call *Maccubuy*, whoſe operations are odd and violent. This plant, a phyſician, to make an extract, caus'd his man to beat in a mortar; but he was ſoon obliged to deſiſt; and the doctor himſelf, tho' at a diſtance off, was ſo affected by the corpuſcles that thence iſſu'd out into the air, that his head, and particularly his face, ſwell'd to an enormous ſize, and continu'd tumid for a long time after. PHYSICS.

'Twill be needleſs to produce more inſtances to ſhew the determinate nature of effluvia, ſmall enough to wander through the air, if we conſider, that many odoriferous bodies, for inſtance, amber, muſk, civet, *&c.* as they will, by the adheſion of their whole ſubſtance, perfume *ſkins*, linen, *&c.* ſo they, in time, perfume ſome bodies diſpos'd to admit their action, tho' kept at a diſtance from them; and that, in peſtilential fevers, and other contagious diſtempers, as the plague, ſmall-pox, *&c.* the ſame determinate diſeaſe is communicable to ſound perſons, not only by the immediate contact of one who is infected, but without it, by the contagious ſteams that exhale from his body into the air.

To conclude with an experiment; having found that volatile and ſulphureous ſalts wou'd ſo work upon ſome acid ones, ſublim'd with mercury, as to produce an odd diverſity of colours, but chiefly an inky one; I took an ounce, or more, of my volatile tincture of ſulphur, made with quick-lime, ſulphur, and ſal-armoniac, and ſtopp'd it up in a vial capable of containing, at leaſt, twice as much: then taking a paper, whereon ſomething had been written with inviſible ink; I laid it down ſix inches from the vial, which, being unſtopp'd, began, upon the acceſs of the air, to emit white fumes into it; and by theſe, what was written upon the paper, notwithſtanding its diſtance from the liquor, quickly became very legible, tho' not quite ſo ſuddenly, as if a paper, written upon with the ſame clear liquor, were held at the like diſtance, directly over the orifice of the vial. And having caus'd ſeveral pieces of clean

paper

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PHYSICS. paper to be written on with a new pen, dipt in the clear ſolution of ſublimate made in water, 'twas pleaſant to ſee how the letters of theſe ſeveral papers, being plac'd within ſome convenient diſtance from the *vial*, would be made plainly legible, and ſome of them more, ſome leſs blackiſh, according to their diſtances from the ſmoaking liquor, and other circumſtances. But 'twas more ſurprizing to ſee, that when I held, or laid ſome of theſe papers, tho' with the written ſide upwards, juſt upon, or over the orifice of the vial, tho' the contained liquor did not reach ſo high, by ſome inches, yet the latent letters would become *conſpicuous* in about a quarter of a minute. And, as it may be obſerved, that in ſome circumſtances, the ſmoaking liquors, and the ſolution of ſublimate, will make an odd precipitate, almoſt of a ſilveriſh colour; ſo, in one or two of our trials, we found a like colour produced by the ſteams of that liquor, in ſome of the colourleſs ink. Nor is it neceſſary to employ a viſibly ſmoaking liquor to blacken the inviſible ink at a diſtance: for I have, to that purpoſe, with good ſucceſs, employ'd two liquors, wherein there was neither ſulphur, ſal-armoniac, nor ſublimate; and cauſing ſomething to be written, with diſſolv'd ſublimate, upon a piece of paper, we folded the paper with the written ſide inwards, and then wrapp'd it up in the midſt of ſix *ſheets* of paper folded, ſingly, on each other, in the form of an ordinary *letter* or packet; ſo that the edges of the incloſing paper being inſerted, one within the other, the fumes might not get into this written paper, but by penetrating through the leaves themſelves: then, that ſide of the packet, on which the ſuperſcription is uſually written, was laid upon the orifice of the vial, and left there about ten minutes; after which, taking off the folded papers, and opening them, we found, that the ſteams had pervaded all the leaves, in which the written paper was incloſed: for, tho' theſe did not appear ſtained, or alter'd, yet the characters, latent before, appear'd conſpicuous.

For farther ſatisfaction, we took a printed book, which we judg'd the fitteſt for our purpoſe, becauſe, the leaves being broad, they might the better preſerve a ſmall paper, placed in the midſt of them, from the exhalations ſideways; and having put the deſign'd paper into this book, and held it to the orifice of the vial, while no leſs than twelve leaves interpos'd, yet, thoſe letters that happen'd to be the moſt rightly plac'd, were made inky in three minutes time; tho' this liquor had been ſo long kept, and ſo often unſtopp'd, to try experiments, that it had, probably, loſt a great part of its moſt ſpirituous, and penetrating particles.

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THE POROSITY OF BODIES, CONSIDER'D.

SECT. I.

The porosity of animal bodies.

AS the greateſt part of the pores in bodies, is too minute to be viſible, ſo the contemplation of them has been thought inconſiderable.

But, ſince moſt qualities depend upon the ſtructure of the minute and inviſible particles of bodies; and ſince interſtices and pores, neceſſarily concur thereto; the doctrine of poroſity muſt be of great importance in natural philoſophy. I will therefore freely communicate what obſervations I have made relating to this ſubject, as they occaſionally occur'd to me; and firſt, as to the poroſity of animal bodies. But I ſhall not here be ſollicitous to diſtribute and range my obſervations; ſince they all conſpire to ſhew but this one thing; that the parts of animals, eſpecially whilſt alive, are furniſh'd with numerous pores *.

* Sir *Iſaac Newton* obſerves, that bodies are much more rare and porous, than is uſually imagin'd. "Water," ſays he, "is 19 times lighter, and, by conſequence, 19 times rarer than gold; and gold is ſo rare, as very readily, and without the leaſt oppoſition, to tranſmit the magnetic effluvia, and eaſily to admit quick-ſilver into its pores, and to let water paſs through it. For, a concave ſphere of gold, fill'd with water, and ſolder'd up, has, upon preſſing the ſphere, with great force, let the water ſqueeze through it, and ſtand all over its outſide in multitudes of ſmall drops, like dew, without burſting or cracking the body of the gold; as I have been inform'd by an eye-witneſs. From all which we may conclude, that gold has more pores than ſolid parts; and by conſequence, that water has above 40 times more pores than parts." *Newton. Optic.* p. 242.

And

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PHYSICS.

Shewn from the ſtructure of their ſtable parts.

And this poroſity is deducible from the frame or conſtitution of the ſtable parts of an animal body; which being a curious engine, admirably contriv'd for the exerciſe of ſeveral functions, it was neceſſary it ſhould be ſupplied with variety of diſſimilar and organical parts. And becauſe the corpuſcles, brought together for ſuch purpoſes, muſt be ſo interwoven, as not exactly to touch one another every where; it will readily follow, that they muſt leave little intervals or pores between them; and that, conſidering the multitude of particles employ'd to make up the body of an animal, and the great difference and variety, in point of bulk and figure, of the corpuſcles requiſite to conſtitute ſuch different parts; both the number and variety of the pores cannot but be very great.

From the manner of their nutrition.

The neceſſity of pores in animal bodies, may, likewiſe, be deduced from their manner of nutrition; for, a great waſte being continually made of their ſubſtance, by the excluſion of viſible excrements, and the avolation of inviſible ſteams; this muſt, neceſſarily, be repair'd by nutrition, of which the beſt account is, that the alimental juice, prepared chiefly in the ſtomach, being impelled to the ſeveral parts of the body, and the corpuſcles of the juice inſinuate themſelves at the pores they find adapted to their bigneſs and ſhape; whence thoſe which are moſt agreeable, being aſſimilated, add to the ſubſtance of the part wherein they ſettle, and ſo repair what was loſt before by that part. This may be illuſtrated from plants, in which, of the various corpuſcles found in the liquors of the earth, and agitated by the heat of the ſun and the air, thoſe, that happen to be commenſurate to the pores of the root, are impell'd into it, or imbib'd by it, and thence convey'd to the other parts of the tree, in the form of ſap; which, paſſing thro' new ſtrainers, receives the alterations requiſite to their converſion into wood, bark, leaves, bloſſoms, fruit, &c. But to return to animals; our argument, from their nutrition, will be much confirmed by conſidering that in children, and other young animals, which have not yet attained their due bulk, the nutrition is ſo large, as to amount to a continu'd augmentation. For, as it is evident that animals grow in all their parts, and in each part, according to all its dimenſions; ſo we cannot well conceive how this ſhould happen, unleſs the nutritive liquor be diſtributed through the whole of the part to be augmented; and to this diſtribution it is requiſite, that the body abound with pores, into which the ſuitable particles of the juice may be admitted.

Having premiſed, once for all, that I often uſe the word ſkin, in the popular ſenſe, without diſtinguiſhing the *Cuticula*, or ſcarf-ſkin, from the *Cutis* it inveſts, I proceed to another topic, whence the poroſity of animals may be argu'd; namely, the great plenty of matter, daily carried off by ſweat, and inſenſible perſpiration. For, ſweat is allow'd to be diſcharg'd at the pores of the ſkin: and ſince there is no penetration of dimenſions, we may conclude, that the matter waſted by ſweat, muſt have ſmall out-lets in the ſkin: and inviſible effluvia may alſo evaporate at the ſame pores. That therefore the ſkins of many animals, tho'

From their ſweat and perſpiration.

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tho' they ſeem cloſe to the eye, may be porous, appears from their ſweating. But becauſe all of them have not been obſerved to ſweat, particularly dogs, we ſhall add ſome other inſtances, to make this more univerſal. PHYSICS.

We may ſometimes, in the ſkin of a living man, diſcern pores, with good microſcopes; and eaſily, on the inſide of gloves, which are made of ſkins dreſſed, perceive numbers of theſe little out-lets, orderly ranged: and tho' ſome of them may be ſuſpected to have been made by the hairs, which grew on the ſkin, before it was dreſs'd; yet, that greater numbers of them are perforations quite through the leather, is manifeſt from the uſual practice of chymiſts, in ſtraining quick-ſilver through ſheep-ſkins. And tho', when a man's ſkin is tanned, it be of a great thickneſs; yet, trying the ſame experiment with the ſkin of a man's arm, I found that quick-ſilver could be ſqueezed out at the pores of this alſo. It is unneceſſary here to enquire, whether theſe little holes be not the orifices of ſmall excretory veſſels, or glands, which *Steno*, and *Malpighi* diſcover'd beneath the *Cuticula*, call'd *Glandulæ Milliares*; for, according to this opinion alſo, a multitude of ſmall perforations muſt be allow'd in the ſkin; and that is ſufficient for my purpoſe, from whence ſoever the poroſity proceeds. But the next obſervation will ſhew, that ſome membranes of animals may give paſſage to tranſpired matter, without being perforated by the excretory veſſels of glands. The ſkins under the ſhell of hens eggs, are of a texture, very fine and cloſe: yet, both theſe, and the ſhells which cover them, are porous; becauſe the eggs, with keeping, manifeſtly loſe in weight: which muſt be imputed to inviſible tranſpiration; and the rather, becauſe in thoſe, which have been long kept, there is found a cavity at one end, that encreaſes with their age, and is made by the ſhrinking of the membrane from the ſhell.

Conſidering the large quantity of matter diſcharged by inſenſible perſpiration in healthful men, the pores muſt, doubtleſs, be very numerous; and much more ſo, than by the drops of ſweat, which wet the ſkin, we uſually imagine. For, *Sanctorius* affirms, that what is barely carried off by inſenſible tranſpiration, ordinarily amounts to more, that is, diminiſhes the weight of a man's body, more than all the viſible excrements together. He adds, if the aliment, taken in one day, amounts to eight pounds, the inſenſible tranſpiration uſually amounts to five. And he elſewhere aſſerts, that in the ſpace of twenty four hours, in the winter-time, an healthy body may exhale above fifty ounces: and ſome trials, both of my own, and others, confirm *Sanctorius*'s obſervations*; allowance being made for the difference of heat between *Italy* and *England*: only, I fear, an over-ſight has been committed by thoſe, who

* Dr. *James Keil* hath given a ſett of obſervations, made by himſelf, after the *Sanctorian* manner, under the title of *Medicina Statica Britannica*; which confirms the doctrine of perſpiration in general, and ſhews the differences of it between our climate, and ſuch as are hotter; tho' it embaraſſes this doctrine conſiderably, that the human body ſeems to take in ſomething from the air, which may encreaſe its weight upon the ballance.

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PHYSICS. aſcribe all the decreaſe of weight, not referable to the groſſer excrements, to what tranſpires at the pores of the viſible parts of the *ſkin*; without taking notice of what is, in expiration, diſcharged through the wind-pipe, and appears manifeſt to the eye, in froſty weather. But tho' I look upon the wind-pipe as the great chimney of the body, in compariſon of thoſe little ones; yet, the number of theſe is ſo very great, that the exhalations which ſteal out at them, muſt be very conſiderable. Beſides thoſe that are diſcharged at the *Aſpera Arteria*, *do*, probably, for the moſt part, iſſue out of the membranes *inveſting the* lungs; which membranes may be look'd upon as external parts of the body, with regard to the air. But we may ſafely allow a very great evacuation, at the pores of a man's ſkin, who is a ſanguineous and hot animal; ſince we ſee that eggs, which are actually cold, tranſpire. Nay, even frogs, which are always cold to the touch, exhale largely; and the decreaſe in weight of ſome animals, ſoon after they are ſuffocated, is conſiderable. We may add, the experiment of holding any part of the body, in warm weather, near to a ſolid or ſmooth ſubſtance, as a piece of ſolid ſteel or ſilver; which will preſently be ſullied with ſteams iſſuing out of the pores.

Farther, the perviouſneſs of the ſkin outwards, may be argued *from* the quickneſs wherewith ſome medicines take away diſcolourations of it by contuſions; which is, very probably, performed by attenuating the matter, and diſpoſing it to perſpire: tho', perhaps, when it is thus changed, ſome part of it may be imbibed again, by the capillary veſſels. *Helmont* ſpeaks much of the virtue of white briony-root, in ſuch caſes; and the fact was lately confirmed, from an experiment made by an acquaintance of mine. I knew an eminent perſon alſo, cured of a contuſion, which made the part look black and frightful, by the bare uſe of hyſop, and freſh butter, applied in the form of a poultis. Nor is it only the ſkin, that covers the viſible parts of the body, which we judge to be thus porous, but alſo the membranes, that inveſt the internal parts. For the two firſt-mentioned cauſes of poroſity, are as well applicable to them, as to the external ſkin; and, in ſome reſpects, the tranſpiration through ſuch pores, ſeems more advantaged, than that through the pores of the ſurface; ſince the parts ſurrounding the ſpleen, liver, kidneys, *&c.* in man, are hot in compariſon of the ambient air; and being alſo wet, which the air is not, the laxity of the pores of the internal parts is doubly befriended: and we conceive both the ſkin, and membranes, to be like net-work; which, in their ordinary ſtate, have a kind of continuity; but, upon occaſion can ſuffer their pores to be every way enlarged, as external agents determine. And this poroſity of the internal membranes, will the more eaſily appear from the perviouſneſs of the bladders of dead animals, even to water; which we have try'd, by putting ſome ſalt of tartar in a clean well-dry'd bladder, and leaving the lower part immers'd in common water, whoſe particles, by degrees, inſinuated themſelves into the bladder, ſo as to diſſolve the ſalt into a liquor:

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liquor: and this experiment ſucceeded, but much more ſlowly, with ſugar inſtead of ſalt of tartar. And there are ſome who pretend, that certain ſyrups, made this ſlovenly way, which they would have paſs for a ſecret, are vaſtly preferable to thoſe made of common water. That even the films, which line the ſhells of eggs, tho' of a very cloſe texture, are, yet, pervious to liquors, appear'd by keeping an ordinary hen's egg, for two or three days in diſtill'd vinegar: for then taking it out, we found it entire, and viſibly ſwell'd. And, what ſatisfy'd us, that the expanſion proceeded from ſome other cauſe, than the mere dilatation of the white, or yolk, or both; the egg now prov'd conſiderably heavier than before its immerſion, notwithſtanding the loſs of its ſhell. And, on this occaſion, may be added, that the *Chineſe* have a way of ſalting eggs in the ſhell. In one of the *Dutch* journals ſent, by the council of *Batavia*, to their principals in *Holland*, I met with ſeveral accounts of ſalted eggs brought by ſea, into *Batavia*, and other ports: after which, meeting with a phyſician who liv'd in *Batavia*, I learnt from him, that ſuch eggs are frequently met with in thoſe parts; he having ſeveral times eaten of them there, and found they retained a briny taſte, when dreſſed. The merchants, of whom I enquired, could not tell me, what way the *Chineſe* employ to ſalt, and preſerve their eggs; but having coated one with clay, and ſuffer'd it to lie, for a competent time, in brine, I found its taſte conſiderably ſalt, when broke. PHYSICS.

I knew a phyſician, who, being tormented with a peculiar kind of colic, reliev'd himſelf by glyſters of ſack; but uſually found, that they would inebriate, and make him giddy: and a chirurgeon, who practiſed in the *Weſt-Indies*, told me, that having dreſſed, with the juice of tobacco, a ſmall ulcer in a woman's leg, the patient, ſoon after grew ſick, and actually vomited. But on this inſtance, I lay no ſtreſs; becauſe the corpuſcles of the tobacco might get in at the ſmall orifices of ſome corroded veſſels, and ſo be convey'd internally, rather by the help of the circulation of the blood, than on account of the poroſity of the parts. But a phyſician of the college of *London*, aſſured me, that he had ſeveral times given himſelf a vomit, by the application of tobacco to his wriſts, and ſome other external parts; and ſome children have been made drunk by cloaths, wetted in the infuſion of tobacco, and applied to their heads, for ſcabbineſs in that part: tho', in this caſe too, the inebriating particles may get in, not at the mere pores, but at the orifices of the capillary veſſels, that were made acceſſible by ſuch little ſolutions of continuity, as are ſeldom wanting in ſuch caſes. But that children may be purged by outward applications, is aſſerted by phyſicians; and an experienced perſon has affirmed to me, that he can almoſt conſtantly purge them by a plaiſter. But it is more conſiderable, what was related to me by a perſon of eminence, who, being indiſpoſed to believe ſuch things, had his hand barely moiſten'd by another, with a ſubtile chymical oil, which the former regarded not, till he found himſelf preſs'd with a motion, like that which a purge would have given him; and was

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PHYSICS. purged four times without griping, or other pain. But to return to the porosity of membranes; it may serve to prove it, that lute-strings, which being only fibres, are the chief parts of which membranes consist, will, sometimes in wet weather, swell so forcibly, as, with noise and violence to break; which proceeds from moist vapours entering at their pores.

From the translation of morbific matter. This porosity of the internal parts of animals may be also confirmed by what happens in the translation of the morbific matter in diseased bodies. For, often the matter, which in the sanguiferous vessels produced a fever, being discharged upon some parts of the head, produces a *Delirium*, or *Phrenitis*; in the latter of which, I have wondered to see the patient's urine like that of a person without a fever. The same febrile matter is discharged sometimes upon the *Pleura*, throat, or intestines; and causes in the first a pleurisy, in the second a quinsy, and, in the third a flux, generally dysenterical. But because most of these translations of peccant humours are made by the circulating blood, I am content to intimate, that some of them may confirm the porosity here spoken of. And this, in effect, is already proved by the same arguments whereby we have shewn, that both the skin, and the internal membranes, are furnished with pores, pervious to particles whose shapes and size are correspondent to them. For it appears, that when morbific matter, whether in the form of a liquor, or of exhalations, chances to have corpuscles suited to the pores of this or that part, it may, by a concourse of circumstances, be determined to invade it; and so dislodge from its former receptacle, and excite new disorders in the parts it removes to.

And from the ingress of effluvia. Another thing, whence the porosity of animals may be argued, is their receiving effluvia from without. For these cannot get into the internal parts of the body, to perform their operations there, without penetrating the skin, and consequently entering the pores of it. Now that things, outwardly applied, may be convey'd to the internal parts, is notorious, in the instances of cantharides; which produce great disorders in the urinary passages, and sometimes cause bloody urine. The same may be also concluded from various effects, even of milder plaisters: for tho' some operate, perhaps, by closely sticking to the skin, hindering perspiration, and fencing the part from the external cold; yet 'twill scarce be denied, that many of them have notable effects from the corpuscles, that plentifully enter at the pores, and act according to their respective natures. The like may be said of ointments, whose effects, especially on children, are sometimes very remarkable: and I have known considerable things performed by them, in an internal disease of grown men, where I should scarce have expected so much from a vegetable unguent. Indeed by mercurial ointments a salivation may be excited; and sometimes, against the physician's will, the corpuscles of the quick-silver get so far into the body, that he is unable to bring them out again. What was said of plaisters is also applicable to *Pericarpia*, or wrist-bands; the better sort of which are often successful in stopping ague-fits: thus by a mixture of currants, hops, and bay-salt well beaten together,

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together, both I, and several more, have been freed from tertians, and other intermittents. The argument will be likewise much strengthned, if those physicians do not deceive us, who ascribe sensible operations to things externally applied in so loose a way, as not to stick to the skin, or perhaps immediately touch it; which some call *Periapta*, and *Appensa*, several whereof are best known by the name of amulets; such as quills of quick-silver, or arsenic, which some hang about their necks, or wear under their shirts against the plague, and other contagious diseases; the blood-stones, worn by others, against hæmorrhages; and that which the women in the *East-Indies* wear for a quite contrary purpose. Now that some of these external medicines answer, I am perswaded by having been, one summer, subject to bleed at the *nose*, and reduced to employ several remedies to check it; what I found most effectual, being some moss of a dead man's skull, tho' it did but touch my skin, till the herb was a little warm'd thereby. A memorable thing of this kind was communicated to *Zwelfer*, by the chief physician to the states of *Moravia*; who having prepared some troches of toads after *Helmont*'s manner, he not only found, that being worn as amulets, they preserv'd him, and all his domestics and friends from the plague; but that having caused them to be put upon the plague-sores of several persons, none of them died; but the venom of the pestilential carbuncles was thereby greatly abated, and the ulcers render'd easily curable by vulgar remedies.

As to the difficulty of conceiving how bodies, actually cold, can emit effluvia, able to penetrate (without moistening it) a membrane of so close a texture, as a man's skin; it may be much lessen'd by considering the pores of bodies, and the figures of corpuscles. For supposing an agreement between 'em, the effluvia of amulets may, in tract of time, easily get passage through the pores of the skin of a living body. And to make this the more probable, I will give an instance of the skin in a dead animal. But this requires a liquor, that I use in such experiments, which is made by exactly mixing flower of brimstone, powder'd sal-armoniac, and good dry quick-lime, in equal quantities; and distilling 'em, by degrees of fire in a retort, till the sand is brought to be almost red-hot; for thus there will come over a smoaking spirit, which must be kept very carefully stop'd, and which, for distinction's sake, I call the permeating menstruum or liquor; and its expirations, the permeating fumes. The experiment is this: We took a very clean piece of polish'd copper, and having wrap'd it either in a piece of lamb's, or sheep's leather, so that it was every way inclos'd, we held it over the orifice of the vial, that contain'd the spirit, at some distance from the liquor; whose fumes, nevertheless, quickly pervaded the pores of the leather, and operated upon the included metal; as appear'd by the deep and lasting tincture it had given to the lower surface of it; tho' the interpos'd leather itself, was not deprived of its whiteness, nor at all sensibly discoloured, yet smelt of the sulphureous steams that had invaded it. And the same experi-

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PHYSICS. experiment ſucceeded, tho' ſomewhat more ſlowly, when a double leather interpoſed between the fumes, and a new piece of copper coin.

I leave it to be conſidered, whether this may not ſuggeſt a conjecture as to that ſtrange phenonemon, recorded by approv'd authors, of lightning which has been found manifeſtly to diſcolour money, without burning the purſe that contain'd it. For, in our experiment, the ſteams which in a trice pervaded the leather, the moſt uſeful matter whereof purſes are made, were ſulphureous, as thoſe which accompany the *Fulmen* are obſerved to be; and tho' theſe, when they invade bodies, are uſually very hot, ours operated when the liquor that emitted them was actually cold. If it be ſaid, that ſometimes money has been found diſcoloured in the pockets of ſuch as were not ſtruck by the *Fulmen*, but had it only paſs near them; we reply, that tho' the entire body, whether fluid or ſolid, if there be any of this latter kind, which the *Latins* call *Fulmen*, (for our *Engliſh* word thunder-bolt ſeems not ſo applicable to a fluid) did not touch them; yet it might ſcatter ſteams enow all around to cauſe the phenomenon. For, a perſon of my acquaintance, having aſcended a burning mountain in *America*, till the ſulphureous ſteams grew too offenſive; he found, amongſt other effects, his money turn'd of a black and dirty colour; ſuch as our ſulphureous ſteams often give both to copper and ſilver coins. But, whether our ſpirits will juſtify my preſent conjecture or no, yet their eaſily pervading the ſkin of a dead animal, will, however, make it probable, that the ſkin of a living man may be eaſily penetrated by external ſteams, of whoſe approach the eye takes no notice; and whoſe operations may, therefore, be unſuſpected. Let phyſicians conſider, what uſe may be made of this obſervation, as to the propagation of contagious diſeaſes, * by the contact of the infected air, diſtinct from the reſpiration of it; and by the penetration of the ſteams, that, iſſuing from ſeveral bodies, invade the ſkin, and may, perhaps, be able to produce, either hoſtile or friendly effects, not uſually ſuſpected to ariſe from ſuch cauſes. We may add, that ſuſpending ſheep's leather in the free air, the vapours in that fluid would, I found, ſo inſinuate themſelves into the leather in wet weather, as greatly to increaſe its weight, of which, dry weather, whether hot or cold, would deprive it.

It may here be proper to add ſome inſtances of the penetrability of membranes to effluvia, if thoſe be ſufficiently ſubtile and correſpondent to the pores of the other. Amongſt the obſervations of phyſicians, I have met with ſome affirming, that cantharides have great effects upon the internal parts of the body, tho' they do not ſo much as touch the ſkin; whence their effluvia muſt be tranſmitted thro' other bodies, before they can penetrate that. *Michael Paſchalius* mentions a chirurgeon, who twice voided blood with his urine; which was occaſion'd by ſome *Spaniſh* flies, that he only carried in a bag; and a phyſician of note mentions another

* *Bellini* has conſider'd this matter, in his laſt propoſitions, *De Febribus*, and demonſtrated it poſſible for ſuch effluvia to enter thro' the ſkin into the body. And the like has been done as to the admiſſion of particles of other kinds, by Dr. *Wainwright*, Dr. *Keil*, &c.

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perſon, who made bloody urine from having carried cantharides in his pocket; and adds, that a like caſe was told him by *Helidæus*, an eminent phyſician. PHYSICS.

We ſee that in linen, the finer and more ſlender the threads are, the cloſer and leſs porous, *cæteris paribus*, is the cloth; whence the thin film that lines the ſhell of an egg, ſeems to be of an exceeding cloſe contexture: yet, even this is not impervious to ſome fumes; for we have ſtained a piece of copper through it, with thoſe of our penetrating liquor. We alſo took a piece of dry'd bladder, and having wrapped it about a new piece of ſilver coin, we held it for ſeveral minutes, over the fumes of the ſame liquor, but could not perceive the coin at all affected; whence we concluded the pores were too cloſe and narrow, to give paſſage to the expirations of the menſtruum; but preſuming, that moiſture would ſomewhat relax them, we wrapp'd up another piece of coin in a wet bladder; and applying this as before, in about two minutes, it was, on the lower ſurface, deeply diſcolour'd. But one of the moſt notable inſtances of the poroſity of the internal membranes of a human body, is that of a relation of mine, a *Britiſh* nobleman, who had, by accident, a great perforation made in his *Thorax*, at which I could directly perceive the motion of his heart. His Lordſhip told me, that when, with a ſyringe, he injected ſome actually warm medicated liquor into his *Thorax*, to cleanſe and cheriſh the parts, he quickly and plainly found in his mouth the taſte, and ſmell of the drugs, wherewith the liquor had been impregnated. And I farther learned, that as he conſtantly wore, upon the incloſ'd part of his cheſt, a ſilken quilt, ſtuff'd with aromatic, and odoriferous powders, to defend the neighbouring parts, and keep them warm; when he came to employ a new quilt, the effluvia would actually mix with his breath, and very ſenſibly perfume it, as appear'd manifeſt to ſuch as ſtood near him; who cou'd perceive that it proceeded not from the outſide of his body. And *Galen* ſays, that water ſweetned with honey being injected at the orifice of wounds, penetrating into the cavity of the *Thorax*, has been, in part, received into the lungs, and diſcharged out of the *Aſpera Arteria* by coughing. Being at the diſſection of a perſon, who had been long moleſted with a ſhort dry cough, which made us expect to find ſomething much amiſs in his lungs; we met with nothing there, and were at a loſs for the cauſe, till coming to the internal part of the cheſt, we diſcover'd between the *Pleura* and the ſubſtance of the intercoſtal muſcles, a certain matter, of the breadth of a crown-piece of a roundiſh figure, and of the conſiſtence and colour of new ſoft cheeſe; which odd matter was concluded to have been the remains of ſome ill-cur'd pleuriſy, and to have tranſmitted thro' the pores of the *Pleura*, ſome noxious effluvia, which frequently irritated the lungs into an irregular and troubleſome motion.

That not only ſingle membranes, but even parts very much compounded, are permeable, and that by liquors none of the thinneſt, is manifeſt in the diſcharges made by hydropical perſons, of a liquor more viſcid than

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PHYSICS. than water, by ſtool and urine, upon the operation of an hydragogue. And it is a pretty common obſervation, that upon the burſting of empyemas into the cavity of the cheſt, the purulent matter hath been voided by ſtool and urine: but, perhaps, it cannot be determin'd, whether this tranſlation be made by tanſudation, or the entrance of the pus into the veſſels; where being once admitted, it may arrive at the kidneys, or any other parts fitted to ſeparate it. We find, however, that the lungs, ſometimes, oddly convey things to diſtant parts of the body. I have often obſerv'd in my ſelf, that when I had aſſiſted in the diſſection of a dog, whoſe blood or body was rankly ſcented, I, for ſeveral hours after, plainly perceiv'd that odour in the excrements I voided by ſiege. And a famous chirurgeon tells us, he cured a ſcirrhous ſpleen by binding over the part a ſponge dipt in lime-water; which muſt, therefore, have penetrated not only the ſcarf-ſkin, and the true *Cutis*, but the muſcles themſelves of the *Abdomen*, and ſome other interpoſed parts. *Galen* alſo obſerves, that bones being ſometimes broken, without piercing the ſkin; when the callus is forming, a portion of the blood which had flowed to the part affected, is carried to the ſkin, and permeates it, ſo as to wet and foul the dreſſings.

The harder parts of the body permeable.

Bones, horns, *&c.* being granted the moſt ſolid parts of the Bodies of animals, I come, in the laſt place, to ſhew, by particular experiments, that theſe alſo have their pores. That the nails are porous, appears from their being eaſily tinged with metalline ſolutions, particularly that of ſilver, in *Aqua fortis*, which can hardly be got out; and the purple ſpots, which I have ſometimes made thereon, by little drops of the ſolution of gold in *Aqua regia*, to obſerve their growth. And the poroſity of ivory may be argued from the ſeveral ways of dying it of laſting colours; for the tinctures that give them muſt penetrate into, and be lodged in the ſubſtance of the ivory. A ſolution of ſilver in *Aqua fortis*, will give it a dark and blackiſh ſtain, not to be waſhed off; and a ſolution of gold in *Aqua regia*, makes it of a fine purple, without heating either the ſolution, or the ivory: copper diſſolv'd in *Aqua fortis*, ſtains it with a bluiſh colour; and without any acid *Menſtruum*, I have, even in the cold, ſtained ivory of a fine and permanent blue, like a turquoiſe, by ſuffering a very deep ſolution of crude copper in an urinous ſpirit, as that of ſal-armoniac, to dry upon it.

But to return to bones; their growth, in all their dimenſions, argues their poroſity: and the marrow found in them, whether it nouriſhes them or no, muſt itſelf be ſupplied by ſome alimental juice, that penetrates into their cavities. Nor does it ſeem improbable, that blood itſelf may be convey'd into their very ſubſtance; as I have been aſſured by eminent anatomiſts, who have obſerv'd blood-veſſels to enter a great way into the larger bones. The blackneſs alſo that bones acquire by heat, and a peculiar kind of fatneſs, which they afford, ſhew that they harbour abundance of unctuous particles, ſeparable from the ſolid ſubſtance, in whoſe pores they muſt, therefore, have been lodged. The lightneſs

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lightneſs of bones, is alſo a great ſign of their poroſity; and further, that they are corroded by tinging liquors. That calcined bones, as alſo thoſe prepared for ſkeletons, will imbibe moiſture in the air, and thereby increaſe in weight, I ſhall not much inſiſt upon, as proofs of their poroſity; becauſe ſome other cauſe may poſſibly be aſſigned for theſe phenomena: I will, however, ſubjoin ſome obſervations made on large ox-bones. *Nov.* 15. we weighed two marrow-bones, and found the one equal'd 29 ounces and half a dram; the other 24 ounces, 4 drams, and 30 grains. *Nov.* 24. The former weighed 29 ounces 6 drams, and the latter 25 ounces, 1 dram, 30 grains. *Decemb.* 28. The former weighed 29 ounces, 3 drams, 55 grains, and the latter 24 ounces, 7 drams, 39 grains. *June* 7. of the following year, the former weighed 29 ounces 2 drams, and the latter 24 ounces 7 drams. From whence, it appears, that bones plentifully imbibe the exhalations of the air, and emit them again, together with ſome of their own, according as the ambient happens to be diſpoſed. And theſe alterations ſhew the bones to abound with pores; ſince the external ſteams muſt find pores to receive them, and the effluvia, upon their receſs, leave pores behind them. And that bones themſelves admit into their ſubſtance, veſſels capable of conveying a nutritious liquor, ſeems credible by what is known to happen in that diſeaſe, which, from the country it moſt infeſts, is called *Plica Polonica*. For though one would think the hairs of men too ſlender to have cavities capable of containing viſible liquors, yet writers of note, and particularly *Sennertus*, tell us, that in this diſeaſe, ſometimes the ſingle hairs will actually bleed, where the ends have been cut off. PHYSICS.

But farther, even particles, neither ſaline nor moiſt, may get into the cavities of human bones; as is evident from thoſe of mercury, where ſalivation hath been practiſed; whereof I have met with a notable inſtance in an eminent profeſſor of phyſic, belonging to the famous hoſpital of incurables at *Rome*, who declares, that in the cavity of the bones of a venereal patient, there was found real quick-ſilver. This, alſo, hath been confirmed to me by other phyſicians experienced in the like caſes. But, particularly, an ancient phyſician, very famous for the cure of this diſtemper, told me of a patient, who had been terribly fluxed by mercurial unctions, and coming afterwards to have one of the grinders of his lower jaw pulled out, becauſe of the pain it had long put him to, a drop of true mercury was found in that ſlender cavity of the root, which admits the ſmall veſſels, from whence the tooth has its nouriſhment and ſenſe. And *Euſtachius Rudius* relates, that he himſelf ſaw ſome bodies diſſected of thoſe who had been anointed for the venereal diſeaſe, in the cavities of whoſe bones no ſmall quantity of quick-ſilver was run together.

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SECT. II.

The porosity of solid bodies.

'TIS not so easy to prove the existence of pores in solid and inanimate, as 'tis in animal and vegetable bodies; however, there are some reasons which induce me to think, that the former are not destitute of them. And, first, by considering the origin and formation of several hard bodies, it will appear, that stones, and even gems themselves, were once either visible liquors, or, at least, very soft substances: and both these kinds of bodies must necessarily consist of, or abound in, minute particles of a determinate size, and shape; from whence it may be probably concluded, that such gems, and other mineral bodies, notwithstanding any hardness they afterwards acquire, retain their pores; since it is no way likely, that corpuscles of various, and very irregular figures, can be so brought together by any agents, as not to leave little interstices between them.

Another argument, to the same purpose, may be taken from the specific gravities of such bodies as the eye does not perceive to be porous. For tho' water is a body of that kind, and tho' its parts be so close, that the attempts to make a manifest compression of it have hitherto proved unsuccessful; yet we find, that stones, clays, metals, and even some woods, with a multitude of other kinds of solids, will readily sink in water, and, by consequence, are specifically heavier than it; which excess of gravity seems inexplicable, without allowing that the corpuscles of such sinking bodies, either lie closer together, or are separately more solid, than those of water: and hence we may conclude, that marble, flints, *&c.* are not free from porosity. The lighter metals, likewise, such as tin, iron, or steel, are above twice heavier, *in specie*, than marble; yet these are exceeded in weight by copper, which I found to be nine times; and that by gold, which, when refined, I found to be nineteen times heavier than water. Whence it seems highly probable, that iron, or steel, are so porous as to suffer metalline matter, equal to them in weight, to be contained in much less than half the dimensions of them. And that gold it self is not destitute of pores, may appear by its dissolution in quick-silver *. If any

* 'Tis no new thing, that the effluvia of the load-stone should pervade the pores of all bodies, even such as are metalline; that the exhalations of the sympathy-ink should do the like at small distances, and that the sulphureous steams of the *Bolonian* stone, when newly calcin'd, should change the colour of gold into that of silver, and the colour of latton into that of gold, tho' closely lock'd up in a box of iron, or other metal; but M. *Homberg* discover'd, that there are substances, which manifestly, to the eye, appear to pass quite thro' the substance of a metal, without displacing its parts, making any break therein, or visibly enlarging its pores. For a salt, composed of quick-lime, distil'd vinegar, salt-petre, sea-salt, and common sal-

any ſhould pretend, that hardneſs is a greater argument of the compactneſs of a body, and its want of pores, than its ſpecific gravity; I add, that tho' emery, which is, indeed, much harder than marble or flint, be far heavier than thrice its bulk of water, yet that weight proceeds from the mixture of a metalline ſubſtance. And diamonds, tho' much harder bodies than emery, are ſo far from being the moſt ponderous, that, having examined them hydroſtatically, I found them not much heavier than either cryſtal or fine glaſs, and not half ſo heavy as the lighteſt metals.

Another proof of this poroſity, ariſes from the very frame and conſtitution of ſuch bodies. For, we cannot ſuppoſe, that the component corpuſcles of the moſt ſolid bodies, ſhould be ſo interwoven, as to touch one another every way exactly, and therefore they muſt of neceſſity leave ſome intervals and pores between them: for there are but very few figures, which will entirely fill ſpace; ſo that, conſidering the vaſt variety of other figures, it is obvious, corpuſcles of ſuch differing ſhapes muſt leave multitudes of little cavities intercepted between thoſe parts, which do not every where touch one another. And even thoſe few mathematical figures, ſaid to fill ſpace, do it rather in a geometrical, than a phyſical ſenſe; becauſe ſuch can never actually exiſt in matter: for no art could poliſh a cube of marble, for inſtance, ſo that no ſmall ſcratches ſhould be left on its ſurfaces, to hinder their perfect contact: and marble it ſelf abounds with internal pores, as may be rationally conjectured from the ſpecific gravity of it, in compariſon of gold and lead.

Having thus diſpatched the arguments *à priori*, we come to our experiments and obſervations, which confirm the ſame doctrine *à poſteriori*. Of theſe, ſome relate to ſolid bodies, of a leſs ſpecific gravity; ſome to foſſils, preſumed to have no metalline parts; ſome to minerals, which are thought to participate of a metalline nature; ſome to metals; and ſome to glaſs. To begin with the firſt: beſides other conſiderations, the poroſity of wood is manifeſt from this experiment. We took a wooden ſhooting-trunk, and having cloſely ſtopp'd one end of it, we poured quick-ſilver in at the other, till it reached to a conſiderable height; when, the lower parts, aſſiſted by the weight of the incumbent ones, iſſued out at the pores of the wood on all ſides, in great numbers of drops, much after the manner of quick-ſilver ſtrained through leather. But, perhaps, the great weight of the quick-ſilver had a conſiderable ſhare in the event. And this obſervation is applicable to the following experiment; when having, by the help of

The poroſity of wood.

ſulphur, will readily, as he ſhews, and of a ſudden, paſs in this manner, thro' an iron crucible ſet in a ſtrong fire, as water paſſe thro' paper; and a bituminous, metallin matter, or cinnabar of ſilver and antimony, will paſs thro' a thin plate of ſilver, and turn it in the parts, both internal and external, thro' which it run, of the colour of lead, without cauſing any farther change therein. See *Memoir. de l'Academ. A.* 1713. *p.* 409.

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PHYSICS. my pneumatical engine, withdrawn the air from one side of a round piece of a board, the air, on the opposite side, press'd so strongly against the surface, as to make way through the pores of it, and get into the cavity, whence the other air had been extracted. This seem'd the more surprizing, because the board, thus permeated, was of strong wood, and considerably thick. But it may here suffice, that when wood is reduced to a certain thinness, it will easily give passage, even to visible, odorable, and tinging corpuscles. For (1.) the fumes of our penetrating liquor, tinged a copper half-penny through a deal-shaving, which did not, when held against the light, discover any perforation. (2.) The same fumes manifestly tinged the same half-penny, through two such shavings of deal, laid upon each other, in less than one minute. (3.) And in about one minute, these fumes tinged it again, through three such shavings of deal, very visibly, but not so strongly as in the first, or even the second experiment; and these trials were made without heat.

Of earthen vessels. That many earthen vessels are porous, appears from their being soaked thro' by oil; some by solutions of nitre, and other salts; and there are very few crucibles, not even the *Hassian*, that will long keep salt of tartar in fusion, without being penetrated by it. I have heard it complain'd of, in the distillation of corrosive materials, as vitriol, and salt-petre, with strong fires, in the earthen vessels commonly made use of, instead of retorts, that a considerable quantity of the finest spirits escape quite through the vessel; so that many ounces are found wanting of the first weight of the matter. And tho' I have observed some earthen bottles, to be hard enough to strike fire with steel; yet I have been assured, that these may have their pores pervaded by spirituous liquors. And a person, curious in making cyder brisk and spirituous, assured me, that it would permeate the very substance of stone-bottles; as appeared both by the taste of that on the out-side, and the less quantity within: and the like observation was confirm'd to me by an eminent physician, who being a great lover of brisk cyder, used to bottle it up carefully. And tho' good *Hassian* crucibles are very closely compacted, yet having dissolved silver in *Aqua fortis*, and I kept it a while in fusion, among quick-coals, it would, without cracking the crucible, soak into it, and pass the pores of it in many places; a multitude of minute globules of pure silver, like so many little drops, appearing on the outside of the vessel.

Of natural stones. In some part of the *West-Indies*, they have a stone, whereof they make large vessels to strain water through; and one of these was sent me as a present; which I found to answer, tho' it was considerably thick. And if the hypothesis, concerning the transparency of bodies from a rectitude of pores, be just, we may draw a very probable argument for the porosity of stones from the phenomena of that odd gem, call'd *Oculus mundi*; for this, when dry, and in the air, is opake, almost like a polished piece of white amber; but if put into fair water, it will gra-

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gradually become quite tranſparent. Now, according to that hypo- PHYSICS.
theſis, the pellucidneſs, which this ſtone acquires in water, may be accounted for, by ſaying, that the liquor getting in at the crooked pores of the ſtone, does, for the time, rectify them, and make them pervious to the ſtreight rays of light; as white-paper, being moiſten'd with oil, has its pores ſo changed, as to make it almoſt tranſparent; but upon the abſence of the imbibed particles, the pores becoming crooked again, reflect thoſe rays of light they ſhould tranſmit. And what countenances this doctrine, the *Oculus mundi* has been found to weigh more in a nice balance, when taken out of the water, than before it was put in.

There appears ſo great a difference, in many qualities, betwixt ſtones and metals, that it is very probable, when the corpuſcles of both come together into one maſs, they will not touch one another ſo, as not to leave interſtices between them; whence I have been induced to think, that ſeveral ſtones are not void of poroſity. For I have obtained metalline parts, both from granats, and emery; tho' the latter be ſo exceeding hard, that it is uſually employed by artificers to work upon iron, and ſteel; and to cut not only rock cryſtal, but ſeveral gems, harder than either that, or ſteel. Hence, alſo, we may probably infer the poroſity of many artificial gems, made by fuſion; for to give theſe the colour of ſapphires, topazes, amethyſts, *&c.* we add to the matter, either ſome prepared metal, as calcined copper, calx of gold, *&c.* or elſe ſome mineral, as zaffora, and *Magneſia*, which abound in metalline parts. Nay, I have ſometimes given the colour by natural gems, as granats; tho' to ſhew that the colouring, which the maſs received from theſe, proceeded from the metalline corpuſcles, that lay hid in the tinging matter, the colour produced was not that of the gem, but very different. And this experiment makes it alſo probable, that even natural gems are themſelves porous; ſince they are made up of ſuch differing ingredients as ſtony and metalline corpuſcles. From the ſame foundation we may, likewiſe, deduce the poroſity of marcaſites; many of which I have obſerved to be not only ſo hard, as plentifully to ſtrike fire by colliſion with ſteel, but more ponderous than many rich ores; for they uſually contain more or leſs of copper, iron, combuſtible ſulphur, a corroſive ſalt, and a certain fixed ſubſtance, which I found to differ from true earth. I might here, alſo, deduce the poroſity of the load-ſtone, as hard and ſolid a body as it is, from its effluvia, and heterogeneity. But the poroſity of marble, and ſeveral other ſtones of like texture, appears from their ſolution by various corroſive menſtruums, and ſome of them even by vegetable liquors, as the juices of lemmons and barberries: but a more ſatisfactory proof ariſes from the ſtaining of white marble, without any fretting liquor, or ſpoiling the texture of it, as I my ſelf have try'd. For an excellent red colour may be made to ſoak into a piece of white marble, almoſt as oil ſinks into leather, without impairing the ſolidity of the ſtone, which, too, will be capable of as fine a gloſs as before. Some other colours might

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PHYSICS. might, alſo, be brought to ſoak into marble. An artificer, whom I introduced, preſented the king with an *Andromeda*, whoſe colours were very vivid; and to ſatisfy his majeſty, that the fine red was not a mere varniſh, I purpoſely broke a marble plate, in whoſe fragments, the pigment had ſunk to a conſiderable depth: and a fine plate of ſuch white marble, with the penetrating pictures of coloured flowers upon it, I yet keep by me; and ſome utenſils of the ſame kind of ſtone, as hafts of knives, ſalt-*ſellers*, *&c.* I have known to laſt for ſeveral years. But there is an experiment, that pleads much ſtronger for the poroſity of ſolid bodies, than even this of ſtaining marble. For, in *Italy*, ſome goldſmiths have a way of imbuing fragments of rock-cryſtal, which is a body much harder than marble, with various colours, ſo as to make them worth ſetting in gold rings. Upon information hereof, I attempted to tinge cryſtal, with indifferent ſucceſs; but ſuſpect that the vehement heat I employ'd made ſmall cracks in ſeveral parts of the ſtone, wherein the pigment enter'd.

Of metals. That metals are porous, may be proved by their ſolution in appropriated menſtruums. But it ſeems more conſiderable, that even groſs bodies will penetrate them without melting: and this we have effected by a cementation of copper-plates with common ſulphur, laid *ſtratum ſuper ſtratum*, in a cover'd crucible, expoſed to a proper degree of fire; the plates being thereby quite altered in colour, and texture; ſome of them appearing of a dirty, others of a fine violet or blue colour. They were, alſo, generally render'd ſo brittle, that it was very eaſy to break them with one's finger, and reduce them to powder. And many of them appeared to have been horizontally divided into two parts, with a manifeſt cavity between them. I could, likewiſe, plainly diſcern a multitude of fibres, reaching from one of the flat ſides of the plate to the other, and running parallel with one another; which circumſtances ſufficiently argue, that they were pierced quite thro' by the ſulphur: beſides, they, alſo, gained in weight by the proceſs, appear'd much thicker, and, laid upon quick coals, yielded a blue flame. By the like experiment we found refined ſilver to be penetrable by ſulphur, which will alſo calcine tin, lead, and iron. Metals are, alſo, penetrable by prepared arſenic. But theſe operations with it are dangerous. There is a ſtill farther way, without the help of ſalts, ſulphur, or arſenic, to make a ſolid and heavy body ſoak into the pores of copper, and give it a durable golden colour, that ſhall ſink conſiderably below the ſurface.

A farther proof, to this purpoſe, is afforded us by the impregnation of ſolid bodies with odorous corpuſcles, as is practiſed on ſword-blades at *Damaſo*, and on many other hard ſubſtances by the *Indians*. An acquaintance of mine had a watch, whoſe metalline caſe ſtrongly retained a perfume, without ſenſible diminution. And, indeed, ſince both arſenic, and common ſulphur, may be incorporated with ſome metals; it ſeems not impoſſible, that ſcented ſubſtances ſhould be admitted into the pores of metalline bodies, and be volatile enough to have their more ſubtile parts fly

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fly off in odorous exhalations. I have made a metalline compoſition, which looked like gold, and of which, I cauſed a ring to be caſt, that retained ſo many inviſible mercurial corpuſcles, as to prove medicinal. PHYSICS.

An inquiſitive nobleman, who had lived in ſeveral parts of *Afric*, told me, that ſome deſcendants of the *Granadine Moors*, made the beſt arms he ever met with; of whom he had a ſword-blade admirably perfumed, as alſo the barrel of a fowling-piece.

Glaſs being reputed the moſt compact body we know, it will be expected I ſhould here ſay ſomething about the poroſity of it. And to proceed with ſome method, I ſhall throw what I have to offer upon this head into two diſtinct propoſitions, and annex obſervations to them. *Of glaſs.*

PROP. I.

It is very probable, that glaſs may be deeply penetrated, even by viſible and tangible bodies.

Having long kept a certain ſpirit of ſalt in a vial, I at length found the glaſs crack'd, and moſt of the liquor run out; but before this happened, it had ſo far corroded the inſide of the glaſs, that in ſome places it was become as thin as paper: and this part, which yet continued glaſs, was lined with a much thicker white ſubſtance, that ſtuck to the ſides of it, and looked and taſted like a kind of odd ſalt; which made me conjecture, that it proceeded from the ſubſtance of the glaſs, which conſiſts of an alkali, as well as of ſand corroded by the ſaline ſpirits of the menſtruum, and coagulated with them into this odd kind of concrete: and 'twas remarkable, that the upper part of the vial, to which the menſtruum did not reach, was not corroded, nor altered, tho' the operation of the liquor reach'd as high as the liquor it ſelf: and an experienced chymiſt aſſured me, that the like thing happened to him. I had alſo another vial corroded by a diſtilled liquor of vitriol, that contained more phlegm than oil: but ſome acid menſtruums will not corrode ſo readily, if they are very ſtrong, as when diluted with a convenient quantity of water. Thus to oil of vitriol it ſelf, when employ'd to make *Vitriolum Martis*, we add water, that it may the better diſſolve the iron. And it ſhou'd ſeem as if that vitriol had ſome peculiar faculty of penetrating and fretting glaſs; for diſtilling a pound of *Dantzic* vitriol, and a pound of ſea-ſalt, when the former had been very lightly calcined, and the latter decrepitated; we afterwards found the heat had here and there melted it, and that the fluxed *Caput mortuum* had corroded the glaſs, fetching off films from it; and thoſe parts which did not appear to the eye thus manifeſtly waſted, ſeemed, by their great brittleneſs, to have been penetrated, ſo that their texture was ſpoiled by the ſaline, and vitriolate corpuſcles.

PROP.

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PROP. II.

Common glaſs is not uſually pervious to chymical liquors, tho' ſtrong and ſubtile, nor to the directly viſible, or odorable expirations of bodies; tho' abſolutely ſpeaking, it is pervious to ſome corporeal ſubſtances.

As for the firſt part of the propoſition; it is manifeſtly agreeable to common experience, that in well-ſtopp'd vials, the moſt ſubtile and piercing menſtruums, whether acid, urinous, or volatile, may be kept. And theſe, tho' in diſtillation, they are often greatly agitated, and perhaps ſubtilized by heat, yet if the luting, that joins the receiver to the retort, be very firm and cloſe, will often burſt the receivers to pieces; which probably would not happen, if the ſpirits could inſinuate and preſs thro' the pores of glaſs. It may be pretended, that ſuch veſſels are thick; but having procured very fine bubbles blown extremely thin, I could not find, that either dry ſalt of tartar, would relent in one, that long lay under water, or that ſtrong ſpirit of ſal-armoniac would penetrate another, which we kept for a great while immerſed in it. Theſe, and ſome other trials, have made me very diffident of the experiments delivered by ſome men, as to the perviouſneſs of ordinary glaſs veſſels to chymical liquors; as that mercury and *Aqua fortis*, being digeſted together in a bolt-head, may, by rubbing the outſide of the glaſs, be made viſibly and palpably to tranſude: which experiment I purpoſely made with care, but without ſucceſs. After all, it muſt be remembred, that I here ſpeak of what uſually happens: for in ſome extraordinary caſes, I do not abſolutely deny, that the general rule may admit of exceptions; which are likelieſt to take place, when the peculiar texture of the glaſs is ſlight; or when the bodies to pervade it, are vehemently agitated by heat; or when, beſides both theſe, their particles chance to have a particular fitneſs to that particular glaſs, they are to paſs through. I have ſeen a glaſs ſo ſoft, that veſſels of it would be manifeſtly prejudiced by liquors, not conſiderably ſharp or corroſive, if they were put in very hot. I have alſo heard another ſort of glaſſes complained of by diſtillers, as ſubject to be injured by corroſive liquors. And I once knew a phyſician, whom ſeveral chymiſts ſuſpected to have the philoſopher's ſtone, but debating his principles freely with him, he own'd he had been miſtaken, and frankly gave me an ingenious account of his proceedings, wherein the principal thing which dazzled him, was, that he had reduced the matter he wrought upon real gold, to ſuch a degree of fuſibility, and ſubtilty, that when he gave too ſtrong a fire, as miſtake or curioſity made him ſeveral times do, the finer part of the metal would ſweat through his glaſſes, and ſtick ſometimes to the outſide of them, and ſometimes to the neighbouring bodies. I objected, that he might here be miſtaken, and that what he thought had come out by tranſudation, rather iſſued at ſome ſmall unheeded crack; but he replied, that he had made the obſervation ſo often,

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often, and with such care, as had fully satisfied him it was a real penetration of the glass, by the attenuated metal. But whatever be judged of this matter, having once distilled spirit of harts-horn, with a very strong fire, into a large and thick receiver, but of a coarse kind of glass; it appear'd that the glass it self was penetrated by some fumes, or subtile liquor, that settled, in strongly scented drops, on the outside of it. But such instances being very rare, and happening but in some cases, or conjunctures of circumstances, they affect not the truth of the first part of our proposition, in the sense wherein it is delivered. And as to the second part, which asserts the perviousness of glass to some corporeal substances, it appears from the free ingress and return, which our sealed thermometers shew, the atoms or corpuscles of cold and heat, are allow'd to make thro' the pores of glass, that contains the rising or falling tincture, or other liquor. And the effluvia of a load-stone will invigorate steel in hermetically sealed glasses: nay, the effluvia of the earth, are readily transmitted thro' glass, and will operate on iron, in vessels hermetically sealed. If light be, as probably it is, either a subtile, and rapidly moving body, or at least requires such an one for its vehicle, it is possible for a body, without difficulty, to pass through the pores of glass; since, by the help of light, we can clearly see the dimensions, shapes, and colours of objects included in glasses. And bodies, far less subtile than those which constitute or convey light, may permeate glass, if they be assisted by an impetuous motion, or a brisk impulse; as I have found by the increase of weight in some metals, exposed, in hermetically sealed glasses, to the action of flame. And, without any sensible heat, I think it not impossible, that glass should be freely penetrated by some kind of corpuscles, which happen to rove about in the air; for, having in two or three vials, closely stopp'd, kept a certain transparent, colourless liquor, it would by fits acquire, and lose an high colour; tho' I could not reasonably impute the changes to any other cause so probable, as the admission and exclusion of some particles, which at that time happened to swim in the air, and now and then to invade, or desert the liquor.

PHYSICS.

There is another argument for the porosity of glass, to be drawn from some of the ways of colouring it, for the windows of churches, and other buildings. For tho' it be, in some cases, rather painted, or superficially enamelled, than tinged; yet, in others, the pigment appears to pierce a little beneath the superficies of the glass; and the yellow colour will not only go deeper, but sometimes seems to penetrate the whole glass from side to side. The methods of staining it, having been hitherto known but to few, the artificers are shy of their secrets; tho' we know, in general, that it is done by covering the plates with mineral pigments, laid on beds of beaten lime, or some other convenient powder, and kept for several hours in a strong fire, yet not strong enough to melt down the plates; by which means the pores of the glass being much opened, and the pigments likewise agitated, and some of them, as it were, vitrified with it, they are made either to pierce into the plate, or at least to stick very closely to it.

The way of colouring glass.

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PHYSICS. But to ſhew, more particularly, that glaſs is porous, we took ſilver calcined by burning ſulphur upon it in the open air, and laid it upon a piece of glaſs, and placed it, with the pigment uppermoſt, upon a few quick coals to neal a while; we gave it about ſuch a degree of heat, as might make, and keep it red-hot, without fuſion; and then ſuffering it to cool by degrees, we found that the glaſs had acquired a yellow, and almoſt a golden colour, not to be waſhed off, or taken away without ſuch ſcraping as would ſpoil the glaſs it ſelf. And, by the way, it is remarkable, that if the fire be made too ſtrong, the dyed glaſs, when held againſt the light, appears of a golden or yellow colour; yet when held from the light, looks blue. Whether the gold-colour, produced by ſilver, favours the hopes of thoſe chymiſts, who work on that metal, upon preſumption, that it is but unripe gold, I muſt not here examine. But, ſince yellow is not the colour of ſilver, the yellowneſs, acquired by our glaſs plates, ſeems to argue, that the ſubſtance of the particles of the ſilver has penetrated into the glaſs; there appearing no way ſo ready to account for this change of colours, as by ſuppoſing the particles of the ſilver to be wrought on by the fixed ſalts, and other fine parts of the glaſs; ſince we know, that metals may afford differing colours, according to the ſaline and other bodies that work upon them; as copper with ſpirit of urine, which abounds in volatile ſalt, gives a deep blue; with ſpirit of ſalt, a fair green; and with *Aqua fortis*, a colour that participates of both. And in making glaſs of lead with minium and white ſand, or cryſtal, the glaſs it ſelf, if well prepared, is uſually of an amethyſtine colour: but if a due proportion of calcined copper be put to it, this metal will not communicate its own reddiſhneſs to the glaſs, but ſo good a green, that ſometimes pieces of this glaſs, ſuch as we have cauſed to be cut, and ſet in rings, might, amongſt thoſe who judge of ſtones only by the eye, paſs for tolerable emeralds.

Whether the art of ſtaining glaſs be loſt. It may here be aſked, whether glaſs can be tinged quite through with a red? and whether the art of dying glaſs be now altogether loſt? We can anſwer the firſt queſtion in the affirmative; tho' the red tincture being communicated not properly by mere penetration of the pigment, but by the incorporation of it with the glaſs, or its materials, by the help of fuſion, I think the experiment of no great uſe in our preſent enquiry: and as to the ſecond queſtion, I wiſh it may be cautiouſly ſtated. For upon the burning of St. *Paul*'s Cathedral in *London*, many pieces of the red glaſs were found broken, and ſcattered about, ſome of which I procured; when I came to examine them narrowly, I was confirm'd, that the redneſs did not penetrate the whole glaſs; for, tho' in other poſtures no ſuch thing could be diſcerned, yet when I ſo held it, that the ſurfaces of the plate lay in a level with my eye, between it and the window, ſo that the broken edge was next my eye, I could plainly ſee the lower part of the plate to be of ordinary uncoloured glaſs, upon which there lay a very thin plate or bed of a tranſparent red pigment, which, it was not impoſſible in ſome places to ſcrape off. But to return to thoſe colorations, that ſeem to

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to penetrate the pores of glaſs; I had once occaſion to diſtil, in a ſmall retort, ſome gold amalgamed with ſuch a fine and ſubtile mercury, that being put to the metal in the cold, they preſently grew hot together: and in the diſtillation of this uncommon mixture, I found the matter had, before it flew away, permanently ſtained about an inch in diameter of the bottom of the glaſs, with a colour, like that of the better ſort of turquoiſe; but being viewed, when it was interpoſed between the window and the eye, it appeared of a ſomewhat golden colour. And an induſtrious perſon, having united gold with a particular quick-ſilver, by my direction, he kept them in digeſtion for ſome months; when the fire having been immoderately increaſed, the ſealed glaſs burſt with a frightful noiſe; and the included amalgam was ſo ſtrangely diſſipated, that ſcarce the leaſt fragment of it could be recovered. But the ſtate of decoction having continued a long time, it ſeems the matter was ſubtilized enough to have a notable operation on the glaſs. For tho' the upper part were blown off, and ſhattered into pieces, yet the lower eſcaped tolerably whole; and I took notice, with delight, that it was tinged throughout of a fine and glorious red, hardly to be matched by that of rubies. PHYSICS.

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THE INTESTINE MOTION OF THE PARTS of SOLIDS.

Reſt, what? THE term reſt, applied to a viſible and entire maſs of matter, commonly ſignifies ſuch a ſtate of it wherein no motion, either of the whole, or its particles, appears to the eye. And in this ſenſe ſeveral bodies may, doubtleſs, be ſaid to be at reſt.

No bodies at abſolute reſt. But there is alſo a more ſtrict and philoſophical kind of reſt, which we may call abſolute; importing the continuance of a body in the ſame place preciſely; with an abſolute negation of all motion, tho' ever ſo ſlow or imperceptible. And in this rigid ſenſe of the word, perhaps no bodies in the univerſe are at reſt.

On the *Epicurean* hypotheſis of the world, the atoms that compoſe all the parts thereof are in perpetual motion. And if we admit the *Carteſian* ſcheme, a ſubtile matter conſtantly paſſes thro' the pores of the moſt ſolid bodies; and therefore, in all probability, is continually ſhaking the minute parts of thoſe that ſeem to be at reſt; the eye taking no notice of the motion: as a gentle wind, ſtealing thro' a grove, will not, to a remote ſpectator, appear to ſtir the leaves and twigs of the trees.

Several fluids, which appear to be continued maſſes of matter, and to reſt as much as the veſſels that contain them, yet have their conſtituent parts in a various actual motion, tho' ſlow and unperceiv'd.

That there may be, likewiſe, ſuch a motion in the minute parts even of ſilver and iron, appears by the heating of thoſe metals almoſt red hot; when tho' the eye diſcerns no motion, the touch will be ſufficiently affected by it; water thrown upon them in that ſtate will be made to boil; and bare agitation, without the aſſiſtance of fire, will enable theſe metals to exhibit the like phenomena.

If a ſteel ſpring be forcibly bent, and kept, for a moderate time, in that poſture, 'twill upon the removal of the force, reſtore it ſelf; but if detain'd very long in that poſition, it gradually loſes its motion of reſtitution;

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ture; and that, where there is a continual endeavour of the parts of a body to put themſelves into another ſtate, the progreſs may be much ſlower than we uſually imagine. And this is farther manifeſt from the durable magnetic power gradually gain'd by a rod of iron, ſtanding for a long time, perpendicularly, expoſed to the air.

An inteſtine motion in the parts of wood.

Lignum Vitæ, tho' it ſeems to be the moſt ſolid wood we know, yet I am inform'd from good hands, that it requires a great length of time to ſeaſon it; ſo that it ought to be kept for twenty years before 'tis fit for ſome purpoſes; otherwiſe the heat of the ſun will crack and cleave it to pieces. And in turning this wood, cavities of ſeveral ſizes have been found fill'd with conſiderable quantities of gum. Now, ſince ſo ſolid a body requires ſo long a time to ſeaſon it, that is, to give it a due compactneſs; and ſince this ſeaſoning ſeems to conſiſt in the gradual avolation of the looſer, aqueous and more fugitive parts, whereby the remaining ſolid ones are brought cloſer together; it follows, that even in the internal parts hereof, there muſt be a motion, tho' too ſlow to fall immediately under the ſenſes. And, if the gum abovemention'd be generated, as 'tis probable, after the tree is cut down; then a groſs, tenacious ſubſtance may penetrate one that is very ſolid and inanimate; which cannot happen without an inteſtine motion among the parts of the wood, and probably, a wonderfully ſlow one of thoſe of the gums.

Nay, wood of a much looſer texture will require a longer time to ſeaſon it than guaiacum. For ancient muſicians and makers of muſical inſtruments declare, that ſome lutes will require forty years to bring them to their due tone; if the wood be thick, and other circumſtances not very favourable. And I have been inform'd, that there are ſome famous inſtruments of the ſame kind, which, to attain their full ſeaſoning and beſt ſound, require the ſpace of fourſcore years.

Stones.

The walls, alſo, of ſome buildings, attain not their due hardneſs and ſolidity in leſs than forty years, or more; whence the motion of their internal parts may well be argued. And there are ſtony as well as metalline marcaſites, which have ſo great a motion in their internal parts, that, if expoſed to the air, they will manifeſt a vitriolate efflorescence on their ſurface, and, in tract of time, burſt to pieces; of which I have ſeen ſome inſtances. And this vitriolate efflorescence will, as I have try'd, happen on the internal ſurface of a broken marcaſite, as well as on the external. But what is more extraordinary, a gentleman, of my acquaintance, had a turquoiſe ſtone, wherein were ſeveral ſpots of different colours, which ſeem'd to him, for many months, to move ſlowly from one part of the ſtone to the other. And, having the ring, wherein 'twas ſet, put into my cuſtody, I drew pictures of the ſpots at different times; and by comparing ſeveral of the draughts together, it evidently appear'd that they ſhifted their places, as if the matter whereof they conſiſted made its way thro' the ſubſtance of the ſtone. And, as far as we obſerved, the motion of theſe ſpots was exceeding ſlow and irregular. An experienced jeweller,

jeweller, likewise assured me, that, in a few turquoise stones, he had observed two different blues, in different parts of the same stone; and that one of these colours wou'd, by slow and imperceptible degrees, invade, and, at length, overspread that part of the stone, which the other before possess'd. And the same gentleman who lent me the spotted turquoise, also shew'd me an agate-haft of a knife, wherein was a certain cloud, which an ingenious person had for some years observed to change its place in the stone.

Diamonds. Glass and diamonds are generally esteem'd bodies of the closest and firmest texture that nature and art afford. If, therefore, we can shew an intestine motion in these, it will hardly be denied in softer substances. Now, diamonds easily become electrical; and some of them will, by being rubbed upon a cloth, be brought to shine in the dark; in both which cases a change of texture, even of the internal parts, is required: and the friction producing this change, doing it immediately by putting the parts of the stone in motion, it seems that a very moderate force may cause an intestine motion, even in the internal parts of diamonds. And, perhaps, more hidden agents may make impressions upon these hardest of bodies. In a diamond-ring which I constantly wear, I have often seem'd to observe a manifestly greater clearness and sparkling at some times than at others; when I cou'd ascribe neither to any manifest cause. And in a rough diamond of mine, I have in a short time observed considerable variations in its degrees of electricity; tho' no manifest cause appear'd of so surprizing a phenomenon. A very ingenious lady, also, who wears abundance of diamonds, assur'd me, she had often observed the like alterations in some of them; which wou'd sometimes sparkle more, and sometimes be far more dull than ordinary, tho' neither the weather nor the foulness of the stones cou'd occasion it. And I have seen a cloudy *Hungarian* diamond, made clear by lying for some time in a cold liquor; and the owner affirm'd it wou'd gradually lose more of its cloudiness, the longer it was detain'd therein. And what I saw my self, sufficed to shew, that changes are producible even in the inward parts of such diamonds, by agents acting without any apparent violence.

And if, as 'tis possible, diamonds may be generated from time to time in the bowels of the earth, perhaps they may, after they seem perfect, and fit for rings, long continue to have an insensible motion thro' the whole of them; whereby the component particles of each may be disposed into a more convenient texture, to constitute an extremely hard body: for diamonds are not equally hard. An expert lapidary assures me, he finds some of them so soft and brittle, that he refuses to cut or polish them, lest they shou'd break upon the mill. And a late *French* author, giving an account of the *Eastern* diamond-mines, tells us, that the stones of the third mine are very clear, and of a good water, but must be ground with stones of the same mine, because with those of another they wou'd be broken to pieces; for they easily break upon the wheel: so that such as are not versed in them, may be easily deceiv'd therein. This

author

author farther adds, that upon most of the diamonds of the second mine, there appears a kind of greasiness, which seems to proceed from some insensible effluvium of the stone, condensed by the air on the surface: which conjecture might be examin'd by an exact balance. A curious lady, very nearly related to me, has a fair ruby, set in a rich ring, which sometimes yields a more vivid fire than ordinary, and at others is manifestly more dull and cloudy, tho' this be in no wise owing, as she expressly assured me, upon repeated observations, to the cloudiness of the weather, or any superficial foulness of the stone. PHYSICS.

And glass. Upon inquiry among the makers of telescopes, and such as use them, I found that the *Venice*-glasses employ'd in them, wou'd sometimes crack, spontaneously, whilst they were in plates, and sometimes after they were ground and polish'd. And I have suspected that some saline corpuscles, more numerous than the nature of the glass requires, may, by slow and imperceptible degrees, so tend towards the surface of it, as either to get out at its pores, or crack, or burst the glass, in attempting to force a passage outwards. And I am inform'd by such as deal much in glass, that there will sometimes, especially in the winter and very moist weather, be a kind of efflorescence, of a saltish taste, manifestly discernible upon the surface of their glasses. I have, also, a thick glass cup, that was, soon after the making, so flaw'd with a multitude of little cracks, that at a distance it look'd white, and not transparent. I have, sometimes, also, had vessels, and other bodies of glass considerably thick, which, of their own accord, have suddenly, and with noise, broke to pieces, tho' some of them had been well sealed. And the like, upon inquiry, I find has frequently happen'd to glassmen and others; particularly, several pieces of large strong looking-glasses, broke in this manner, have been shew'd me, by the maker, who assured me this wou'd sometimes happen, after they had long stood in his shop; when they wou'd fly asunder with such violence, as to break some adjacent plates, tho' thick and strong. Nay, this disposition to break, has continued in some sorts of glass for several years; particularly in a parcel that had lain by for above four years; which when the master of a glass-house came, as he told me, at length to open, and range in order, a fourth, or a third part of the whole number, soon after crack'd spontaneously. Now whether we solve these phenomena on the atomical or *Cartesian* hypothesis, there will appear to be an intestine motion in glass; which being easily made electrical by friction, and as easily crack'd by applying a hot iron first, and then cold water to a part of it, farther confirms this doctrine. Glass, also, swells considerably, or alters its figure after 'tis blown, and seems to be sufficiently cooled. For when white glasses are blown into a mould, they cannot, when cold, be put again into the same; and require the cells of guard-vials to be larger than the mould. From the whole, I will not positively infer, there is no such thing as absolute rest in nature, but, probably, there is not; since we have not found it in those bodies, where it might, with reason, be the most expected.

CON-

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CONSIDERATIONS
UPON THE
NATURAL
AND
PRETER-NATURAL STATES
OF
BODIES,
Especially the AIR.

The common notion of the natural and preter-natural states of bodies, obscure, unjust, and liable to be misapplied.

THE famous distinction between the natural and preter-natural or violent state of bodies, as well inanimate as animate, has been universally admitted; and hypotheses and reasonings are daily, without the least scruple, founded upon it, as if it were most certain, that nature had purposely framed bodies in a determinate state, and were always watchful that they should not by any external violence be put out of it.

But notwithstanding so general a consent in this point, I confess, I cannot yet be satisfied about it, in the sense wherein it is usually taken. 'Tis not that I believe, there is no sense wherein a body may be said to be in its natural state; but that I think the common distinction of a natural and violent state of bodies has not been clearly explained, and considerately settled; and that it is not only ill grounded, but oftentimes ill applied. For, since whatever state a body is put into, or kept in, it obtains or retains that state, according to the universal laws of nature; in this sense, the body propos'd must be in a natural state: but, upon the same ground, 'twill be hard to deny, that those bodies which are said to be in a violent state, may, also, be in a natural one; since the violence, they are presumed to suffer from external agents, is, likewise, exercised no otherwise than according to the established general laws of nature. 'Tis true, when men look

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look upon a body as in a preter-natural ſtate, they have an idea of it different from that which they had whilſt they believ'd it to be in a natural one: but perhaps this difference ariſes chiefly from hence, that they do not conſider the condition of the body, as it reſults from the univerſal laws ſettled among things, and relates to the univerſe; but eſtimate it with regard to what they ſuppoſe is convenient or inconvenient for the particular body it ſelf. However, it ſeems to me, that the determining a body to be in a natural or preter-natural ſtate has much more in it, either of caſual, or arbitrary, or both, than they are aware of. For, we often think a body to be brought into a violent ſtate, not becauſe the former was really leſs ſo, but becauſe there is a notable change made in it, by ſome agent, which we alſo take notice of; whereas, before the action of that agent, if the body were under any violence, 'twas exercis'd by uſual, but unobvious agents; tho' perhaps, their action were not leſs, but diſregarded more. And ſometimes, alſo, no more is to be underſtood by a body's being forc'd from its natural ſtate, than that it has loſt what it had immediately, or a conſiderable time, before ſome notable change. PHYSICS.

Now, matter being deſtitute of ſenſe and appetite, cannot be truly and properly ſaid to affect one ſtate and condition more than another; and conſequently has no true deſire to continue in any ſtate, or to recover it when once loſt: and inanimate bodies are in their ſtate, not as the material parts they conſiſt of choſe or deſired to make them, but as the natural agents which brought together and rang'd thoſe parts, actually made them. Thus, a piece of wax is unconcerned, whether you give it the ſhape of a ſphere or a cone; and whether, when it has that form, you change it into any other; the matter ſtill retaining, without willingneſs or unwillingneſs, becauſe without perception, that figure or ſtate which the laſt action of the agent determined it to, and let in.

Whether water be not as properly thaw'd ice, as ice is frozen water.

The moſt uſual inſtance produced to ſhew, that a ſtate is natural to a body, and that being put out of it, by external cauſes, it will, upon the ceſſation of their violence, be reſtored thereto, is, that water being heated by the fire, returns to its native coldneſs, as ſoon as that adventitious heat vaniſhes; and ſo when, by an exceſs of cold, it is congeal'd into ice, it, upon a thaw, loſes that preter-natural hardneſs, and recovers the fluidity naturally belonging to it: and the ſame may be, likewiſe, ſaid of butter, which, being melted by external heat into a liquor, does, upon the ceſſation of that heat, grow a conſiſtent body again. But as to the coldneſs whereto water heated by the fire, returns when 'tis remov'd thence, it may be ſaid, that the acquired heat conſiſting but in the various heat and briſk agitation of the corpuſcles of the water by an external agent, it is no wonder, when the agent ceaſes to operate, that the effect of its operation ſhould ceaſe too, and the water be left in its former condition; whether we ſuppoſe it to have been heated by the actual pervaſion of the cor-

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PHYSICS. puſcles of the fire, which by degrees fly away into the air; or that the heat proceeds from an agitation imparted by the fire to the aqueous corpuſcles, which muſt, by degrees, loſe that new agitation, by gradually communicating it to the contiguous air and veſſels; ſo that, if the former agitation of the particles of the water were, as is uſual, much more languid than that of our organs of feeling, in which faintneſs of motion, the coldneſs of the water conſiſted, there will be no need of any poſitive internal form, or any care of nature to account for the waters growing cold again. This may be confirmed by conſidering what happens to ice, which is ſaid to be water brought into a preter-natural ſtate by an exceſs of cold. For, I doubt, 'twill not be eaſily demonſtrated, that, with regard to the nature of things, and not to our arbitrary ideas of them, ice is water preter-naturally harden'd by cold, and water not ice preter-naturally thaw'd by heat. For if you urge, that ice, left to it ſelf, will, when the frigorific agents are removed, return to water; I anſwer, that, not to mention the ſnow and ice that lie all the ſummer long unthawed upon the tops of the *Alps* and other high mountains, I have learn'd, by inquiry, purpoſely made, from a phyſician, who for ſeveral years practiſed in *Muſcovy*, that in ſome parts of *Siberia*, the ſurface of the ground continues more months of the year frozen, by what is call'd the natural temperature of the climate, than thaw'd by the heat of the ſun; and that a little beneath the ſurface of the ground, the water, which chances to be lodged in the cavities of the ſoil, continues frozen all the year; ſo that, when in the heat of ſummer the fields are cover'd with corn, if you dig a foot or two deep, you ſhall eaſily find ice and a frozen ſoil: whence a man born and bred in the in-land part of that country, and inform'd only by his own obſervation, may probably look upon water as ice violently melted by the ſun, whoſe heat is there ſo vehement, as to ripen the harveſt in leſs time than in our temperate climates, will be eaſily credited.

Whether a liquid or a conſiſtent form be the natural one of butter, &c.

On the other ſide, we in *England* look upon melted butter, as brought into a violent ſtate by the operation of the fire; and therefore think that, when being remov'd from the fire, it becomes a conſiſtent body again, it has but recover'd its native conſtitution. But there are ſeveral parts of the *Eaſt-Indies*, and, I doubt not, of other hot countries, where the Inhabitants, if they ſhould ſee conſiſtent butter, (as ſometimes by the care and induſtry of the *Europeans* they may do) they would think it brought to a preter-natural ſtate, by ſome artificial way of refrigeration. For in thoſe parts of the *Indies* I ſpeak of, the conſtant temper of the air being able to entertain as much agitation as ſuffices for fluidity in the parts of what, in our climate, would be butter, it were in vain to expect, that, by being there left to it ſelf in the air, it ſhould become a conſiſtent body. And I have learn'd,

learn'd, by diligent inquiry of ſea-men and travellers, both *Engliſh* and others, who were eye-witneſſes of what they told me, that, in ſeveral parts of thoſe hot regions, butter, unleſs by the *Europeans*, or their diſciples, purpoſely made in the cold, remains fluid all the year long, and is ſold, or diſpens'd, not as conſiſtent bodies by weight, but as liquors, by meaſure. To ſtrengthen this obſervation, I ſhall add, that a learned man, who practis'd phyſic in the warmer parts of *America*, affirmed to me, that he met, in ſome places, with ſeveral drugs, which, tho' they there ſeem to be balſams, as turpentine, &c. are with us, and retain'd that conſiſtence in thoſe climates; yet when they come into our colder regions, harden into gums, and continue ſuch both winter and ſummer. On the other hand, inquiring of a traveller, vers'd in phyſical affairs, about the effects of great heat in the in-land part of *Africa*, where he had lately been; he told me, among other things, that roſin of *Jalap*, which, when he carried it out of *England*, was of a conſiſtence not only dry, but brittle, did, when, and a while before he came to *Morocco*, melt into a ſubſtance like turpentine; ſo that ſome of it which he had made up into pills, would no longer retain that ſhape, but remain as it were melted all the while he ſtayed in the neighbouring country; tho' when he came back to the borders of *Spain*, it return'd to its former conſiſtence. And having my ſelf conſider'd ſome parcels of gum *Lacca*, newly brought aſhore from the *Eaſt-Indies*; tho' it be a hard and ſolid gum, yet I found by ſeveral inſtances, that, in paſſing thro' the torrid zone, various pieces of it, notwithſtanding the ſhelter afforded it by the great ſhip it came in, had been, by the heat of the climate, melted, and made to ſtick together; tho' afterwards they regain'd their former conſiſtence, but not altogether their former colour. And I learn'd from a particular acquaintance of mine, who brought me ſeveral rarities out of *America*, that, having at the place where 'twas made, among other things furniſhed himſelf with a quantity of the beſt aloes, he obſerved it to be, whilſt he ſail'd thro' very hot climates, ſo ſoft, that, like liquid pitch, it would often have fallen out of the wide-mouth'd veſſel wherein he kept it, if he had not, from time to time, been careful to prevent it: but when he came within a hundred leagues of the coaſt of *England*, it grew hard, and ſo continued; tho' this were in a very warm ſeaſon of the year, being about the dog-days.

PHYSICS.

Whether the atmoſphere be in a natural or a violent ſtate.

And as to that moſt obvious body, the air, or atmoſphere, wherein we live and breathe, tho' ſeveral opinions and arguments are founded upon what authors call its natural and preter-natural, or violent ſtate, yet he who conſiders, will find it no eaſy thing to determine what ſtate of the air ought to be reputed its truly natural ſtate, unleſs in my ſenſe of that expreſſion. I will not inſiſt on the heat and coldneſs of the air; for thoſe being manifeſtly very different in the depth of winter, and in the heat of ſummer, and in differing regions of the air, as at the top and bottom of high mountains, at the ſame time, and conſtantly

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ſtantly in different regions of the earth, as in *Barbary* and *Greenland*; 'twill not be ſo eaſy to determine, what is its natural ſtate: but that only which I ſhall now conſider, is its ſtate or tone in reſpect of rarity, and denſity. For, ſince the air is ſuppoſed to be condenſed by cold, and expanded by heat, I demand, at what time of the year, and in what country, the air ſhall be reputed to be in its natural ſtate? If you name any one time, as the winter, or the *ſummer*, I aſk, why that muſt be the ſtandard of the tone of the *air*, rather than another ſeaſon, or at leaſt excluſive of all others? The like difficulty will alſo ariſe about the climate or the place. And theſe ſcruples are the more allowable, becauſe learned men have deliver'd, that in ſome countries the mercury in the *Torricellian* experiment, is kept higher than in others, (as in *Sweden* than in *Italy*;) and our barometers inform us, that often in the ſame place and day, the quick-ſilver in the ſame inſtrument conſiderably varies its height; which ſhews, that the air or atmoſphere muſt neceſſarily vary its weight, and therefore probably its degree of rarity or denſity.

But I have a further conſideration to propoſe in this affair: for, what if it ſhall appear, that neither in winter nor in ſummer, in *Sweden* or in *Italy*, or in whatever country, region, or ſeaſon you pleaſe, the air we breathe is in any other than a preter-natural ſtate; nay, that even when we have vehemently agitated and expanded it, by an intenſe fire, it is not yet violently rarified, but violently crouded; unleſs, in the ſenſe above-mention'd, we underſtand the preter-natural ſtate of rarification in the air with reſpect to the tone it had before the laſt notable change was produc'd in it? This will, I queſtion not, ſeem a ſurprizing paradox: but yet, to make it probable, we need only reflect upon two or three air-pump experiments; whereby it appears, firſt, that the air being a body abounding with ſpringy particles, not deſtitute of gravity, the inferior muſt be compreſs'd by the weight of all the incumbent: and next, that this compreſſion is ſo great, that tho' by the heat of the fire we could not bring a portion of included air to be expanded to above fourſcore times its former dimenſions; yet without heat, by barely taking off the preſſure of the ſuperior air, by the help of our pneumatical engine, it was rarified more than twice as much: and I have, more than once, rarified it into above five hundred times its uſual ſpace; ſo that if, according to what is generally allow'd and taught, a body be then in a preter-natural ſtate, when by an external force it is kept in a condition from which it inceſſantly tends to get free; and if it be then moſt near its natural ſtate, when it has the moſt proſperouſly endeavoured to free it ſelf from external force, and comply with its never-ceaſing tendency; if this be ſo, I ſay, then the air we live in is conſtantly in a preter-natural ſtate of compreſſion by external force. And when it is moſt of all rarified by the fire, or by our engine, its ſprings have far more conveniency than before to diſplay themſelves,

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ſelves, which they continually tend to do, it anſwerably approaches to its natural ſtate, which is to be yet leſs compreſſed, or not at all. And I have carefully try'd, for many months together, that, when the air has been rarified much more than even a vehement heat will bring it to be, yet, if it were fenc'd from the preſſure of the external air, it would not ſhrink to its former dimenſions: as if it had been put into a violent ſtate, from whence nature would reduce it; but it continued in that great and ſeemingly preter-natural degree of extenſion, as long as I had occaſion to obſerve it. We might here ſhew, that this odd conſtitution of the air is ſo expedient, if not neceſſary for the motion, reſpiration, and other uſes of animals, and, in particular, of men, that the providence and goodneſs of the wiſe author of the univerſe is thereby ſignally declared. But we are not here to employ final cauſes. From the whole we may learn two conſiderable things. And firſt, from what was ſaid of the air, the natural ſtate of a body may, ſometimes, be allow'd to be not that which it really has a tendency to attain, but that whereto it is brought, and wherein it is kept by the action or reſiſtance of neighbouring bodies, or by ſuch a concourſe of agents and cauſes as will not ſuffer it to paſs into another ſtate. And ſecondly, we may hence learn, that, whatever be ſaid of nature's never miſſing her aim, and that nothing violent is durable; yet, bating an inconſiderable portion of aerial particles at the upper ſurface; for aught we know, the whole maſs of the air we live in, and which ſurrounds the terraqueous globe, has been from the beginning, and will to the end of the world, be kept in a ſtate of violent compreſſion. PHYSICS.

OBSER-

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OBSERVATIONS
UPON THE
EFFECTS of LANGUID
AND
UNREGARDED MOTIONS.

HOW superficially ſoever the local motion of bodies is treated of by the ſchools, who aſcribe almoſt all ſtrange things to ſubſtantial forms; we, who endeavour to reſolve the phenomena of nature into matter, and motion, guided according to ſettled laws, muſt duly obſerve its operations. And tho' mathematicians and philoſophers have, of late, applied themſelves to conſider the nature and laws of motion, yet the ſubject can never be too much cultivated, and ſome parts of it have ſcarce hitherto been touch'd upon *.

But,

* The laws of motion, and colliſion, both in elaſtic and unelaſtic bodies, in all kinds of mediums, and in all poſſible caſes, are demonſtrated by the geometricians of the laſt and the preſent age; as particularly by Dr. *Wallis*, Sir *Chr. Wren*, M. *Huygens*, M. *Varignon*, the *Bernoulli's*, Dr. *Keil*, and above all, by the great Sir *Iſaac Newton*, whoſe three axioms, or grand laws of motion, for their extreme uſefulneſs in philoſophy, we ſhall here ſet down, as they are deliver'd by the incomparable author himſelf.

1. "All bodies will for ever remain in "their ſtate either of reſt or uniform rectilinear motion, unleſs compell'd to change "either ſtate by ſome force impreſs'd upon "them.

"Projectils continue in their motions, being for the reſiſtance of the air, and the force of gravity, whereby they are impell'd "downwards. A top, whoſe parts, by reaſon of their cohеſion, conſtantly turning, "form a rectilinear motion, wou'd ſpin till "it is ſtop'd by the reſiſtance of the air: "but the vaſt bodies of the planets and comets longer preſerve their progreſſive circular motions, in ſpaces where they find leſs reſiſtance.

2. "Every change of motion muſt be proportional to the moving force impreſs'd, "and happen in the ſame ſtrait line wherein that force is directed.

"If a certain force produces a certain motion; twice that force will produce double "that motion; and thrice that force treble "that motion; whether it be impreſs'd all "at once, or by ſucceſſive degrees. And "this motion, having always the ſame direction with the power that cauſes it, "muſt, if the body were before moving the "ſame way therewith, be added to the motion

But, before I enter upon particulars, I muſt premiſe in general, that we are not to look upon the bodies, wherewith we are concern'd, as ſo many lumps of matter, which differ only in bulk and ſhape, or that act upon one another merely by their own diſtinct and particular powers; but as having peculiar and different internal textures, as well as external figures; on account of which, many of them muſt be conſidered as engines, ſo framed, and placed among other bodies, that ſometimes agents, of themſelves invalid, may have notable operations upon them; becauſe a great part of the effect is due to the action of one part of the body it ſelf upon another †. And there are, perhaps, more accounts, than we have yet thought of, upon which local motion may perform conſiderable things; and therefore I would not be underſtood to exclude the reſt, tho' I ſhou'd hereafter take notice but of a few of theſe accounts. Now amongſt the ſeveral things, upon account whereof we uſually overlook, or under-

" motion of that body; if a contrary way, " be ſubtracted from it; if impreſs'd ob- " liquely, it muſt be added obliquely; " and ſo be compounded with it, according " to the direction of both motions.

3. " Re-action is ever contrary to and " equal with action; or in other words, " the action of two bodies upon one ano- " ther are always equal, but in contrary di- " rections.

" Whatever preſſes or draws a body, is " it ſelf equally preſſed or drawn by that bo- " dy. Upon preſſing a ſtone with the fin- " ger, the finger is preſs'd by the ſtone. " When a horſe draws a ſtone by means " of a cord faſten'd thereto, the horſe, if " I may uſe the expreſſion, is equally drawn " back to the ſtone; for the cord being e- " qually ſtretch'd both ways, will by the " ſame endeavour to relax it ſelf, force as " well the horſe towards the ſtone, as the ſtone " towards the horſe; and hinder the one from " advancing forwards, as much as it retards " the other. If one body ſtrikes againſt " another, and by its force changes, in any " manner, the motion of that other; tho " firſt body will, likewiſe, ſuffer the ſame " change of motion, but in a direction con- " trary to the force of the latter; becauſe " the preſſure in this caſe is mutual. Now " in ſuch actions as theſe, there happens " an equal change, not of the velocities, " but of the motions of the bodies concer- " ned; I. mean, if thoſe bodies are not " otherwiſe hinder'd. For the changes of " velocities, which, in like manner, hap- " pen in contrary directions, muſt ſince, the " motions are equally changed, be recipro- " cally proportional to the bodies. And " this law holds good in attraction."

Many excellent corollaries flow from theſe laws. As a ſpecimen, take the following, which is demonſtrated from them by the author himſelf, and made great uſe of in his philoſophy.

" A body, moving with a compound force, " will deſcribe the diagonal of a parallelo- " gram, in the ſame time that it wou'd " the ſides thereof, if that force were di- " vided." From hence the effects of all the mechanical powers are eaſily demonſtrated; hence all compound motions are reſolvable into ſimple ones; and hence Sir *Iſaac* has proved, that the planets move in fix'd plains, and deſcribe areas about the ſun, proportional to the times. See *Newton. Princip. p.* 12, 13, 34, 375.

† *M. Homberg* tells us, that the ſimple motion of a mill turn'd a bottle of wine, which was fix'd to it, into excellent vinegar, in three days time; and that, by the ſame means, he had from a pound of quick-ſilver, in three months time, four or five ounces of a blackiſh powder. *Hiſt. de l'Acad. A.* 1700. *p.* 14.

value

value the efficacy of local motions, the chief are referable to the following obſervations.

The great efficacy of celerity.

1. *We are ſeldom aware of the great efficacy of celerity in ſmall bodies, and eſpecially if they move but thro' a ſmall ſpace* *. What rapid motion can do, may be judged by the powerful effects of bullets, ſhot out of our common cannons, in compariſon of the vaſt and unwieldy battering-rams of the ancients. Other examples of a like nature might be alledg'd; but the latter part of the propoſition is what I *am moſt* concern'd to prove.

Having ſometimes cauſed an oblong piece of iron or ſteel to be turned, and placing my naked hand, at a convenient diſtance, to receive the little fragments as they flew off from the rod; they were ſo intenſely heated, by the quick action of the tool upon them, that they ſeem'd almoſt like ſo many ſparks of fire. And an expert workman in braſs aſſured me, that the heat in the little fragments thrown off, when he turn'd that metal, was ſometimes very offenſive to his eyes; and that when he employ'd a rough tool, which took off greater chips, he had found the heat ſo vehement, as not only to ſcorch his eye-lids, but the hard ſkin of his hands; for proof whereof, he ſhewed me a little bliſter, which had been ſo raiſed. And I learn'd from a famous artiſt, employ'd about the finiſhing of caſt ordnance, that when with a ſtrong peculiar engine, he and his aſſociates turn'd great guns, to bring the ſurface to a ſmoothneſs, the tools would ſometimes throw off bits of metal, ſo heated, as to burn the fingers of thoſe who ventured to touch them. An experienced artificer alſo, aſſured me, that turning in braſs, the little fragments acquired an intenſer heat, than thoſe of iron. And cauſing an artificer very briſkly to turn a piece of ordinary wood, whilſt I held my hand not far from it, the chips which flew off, ſtruck it in many places, with that briſkneſs, that 'twas with pain I endur'd the heat, they produced. It is farther conſiderable to our preſent purpoſe, that by an almoſt momentary percuſſion, with no great force, the parts even of a vegetable, may not *only* be intenſely heated, but brought to actual fire; as we have tried by the ſtriking a good cane with a ſteel, or the back of a knife; for upon this colliſion, it would yield ſparks like a flint. So, likewiſe, by ſcraping good loaf-ſugar with a knife, numerous ſparks will be produced; but upon the colliſion of a flint and ſteel, not only fire, but even, vitrification, which the chymiſts eſteem to be the ultimate action of fire, is inſtantaneouſly produced; for the ſparks which here fly off, are uſually real and permanent parcels of ſtone, vitrified by the vehemence of the motion. And that this vitrification may be of the ſtone it ſelf, tho'

* 'Tis an axiom, or acknowledged law of motion, that any body, how ſmall ſoever, will move the largeſt, by impinging with the leaſt aſſignable velocity, upon it; for, as we juſt now ſaw, action and re-action are equal.

ſteel,

ſteel is a metal of a far more fuſible nature, I am induced to think, becauſe flints will, by colliſion, ſtrike fire with one another: the like alſo may be done with rock-cryſtal, and even with diamonds, on the mill whereby they are cut; tho' fire is not allow'd to fuſe them. PHYSICS.

Nor are fluid bodies, tho' but of ſmall dimenſions, to be excluded from the power of making conſiderable impreſſions on ſolids; if their celerity be great. Whether the ſun-beams conſiſt of very minute corpuſcles, which continually iſſuing out of the ſun's body, ſwiftly impel one another forwards in ſtrait lines; or whether thoſe beams are made by the briſk action of the luminary upon the contiguous fluid, and propagated every way in ſtrait lines, thro' ſome ethereal matter harboured in the pores of the air; it will be agreeable to either hypotheſis, that being refracted or reflected, by a burning glaſs to a focus, they by their concourſe, compoſe a ſmall portion of fluid matter, ſo violently agitated, as to kindle green wood in leſs than a minute, and to melt not only tin and lead, thinly beaten, but leaf-ſilver and gold *.

The operation of ſmall portions of fluid matter on ſolid bodies will be exemplified hereafter; I ſhall here only, in general, point at the great and ſurprizing effects of lightning. The laſt inſtance of its power within my acquaintance was, the melting of a metal by the flame, in its paſſage, which probably laſted but the twinkling of an eye. And that even a ſmall parcel of air may communicate a conſiderable motion to a ſolid body, is confirmed by the violent force of a bullet ſhot out of a good wind-gun; which I found by trial would be flatted, almoſt into the figure of an hemiſphere, by being thus thrown againſt a metalline plate. And farther, to ſhew what a vehement agitation may be communicated to the parts of a ſolid body, by celerity; going to take up this bullet, I found it too hot to be, without pain, held betwixt my fingers.

2. *We are too apt to think that fluid bodies becauſe of their ſoftneſs, cannot, by their bare motion, eſpecially if inſenſible, have any ſenſible effect upon ſolids; tho' the fluid moves and acts as an entire body.* It is not my deſign here to inſiſt on the efficacy of ſuch fluids as may have their motions diſcovered by the eye, as flowing water; or perceived by the touch, as winds; but of ſuch only, as we do not immediately ſee or feel. *The force of fluids upon ſolids.*

* M. *Villette* lately exhibited a burning concave forty-ſeven inches wide, and ground to a ſphere of ſuch a radius, that its focus was about thirty-eight inches from the vertex of the glaſs. The metal of it was a mixture of copper, tin, and tin-glaſs. This concave melted iron-ore in 24″, began to calcine talc in 40″, and as M. *Villette* ſaid, wou'd calcine aſbeſtos. It melted a ſixpence in 7″½ and a half-peny in 16″. It turned an emerald into a ſubſtance like a turquoiſe-ſtone; and diminiſh'd a diamond, that weigh'd four grains, ⅞ of its weight. See *Philoſoph. Tranſact.* N°. 360. *p.* 976.

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PHYSICS. It has been frequently obſerved, that, upon the diſcharge of ordnance, not only the ſound may be diſtinctly heard at a great diſtance, but that the tremulous motion of the air, which produces ſound, has been able to ſhake, and ſometimes to break glaſs-windows afar off; eſpecially, when they ſtand in the way, wherein the propagation of the ſound is directly made. And tho', in ſome inſtances, it may be urged, that ſuch effects are produced from the motion of the earth, immediately ſhook in the exploſion; yet I ſee no neceſſity here, of having recourſe to any thing, but the undulating motion of the air; ſince the like may be produced by motion continued thro' fluids. *Borelli*, diſcourſing of the force of percuſſion, has this remarkable paſſage.

" I was," ſays he, " at *Tauromenium* in *Sicily*, when the mountain " *Ætna* broke out near *Enna*, a town diſtant about thirty miles from *Tau-* " *romenium*; whilſt the chaſm ſent out, now and then, with great " noiſe, fire and flame; all the houſes were ſenſibly ſhaken: and it " was obſerved, that ſuch as looked directly towards the chaſm, were " moſt agitated; thoſe looking otherwiſe, ſhaking more ſlowly." Upon which fact he thus argues: " Had this trembling been occaſioned " by the ſhaking of the ground of *Tauromenium*, all the houſes would " have been equally ſhaken; ſince this inequality of motion could " not be aſcribed to their different ſituation. Hence, then, we muſt " needs conclude, that the agitation was produced by the impreſſion of " the air upon the walls of the houſes; which demonſtrates the great " efficacy of a ſound, tho' at thirty miles diſtance."

I was once invited by an engineer, to ſee trial made of an inſtrument, which he had contrived ſuddenly to ſink a ſhip; but in the experiment, which was ſucceſsfully made upon an old frigate, the exploſion was ſo great, that it raiſed a kind of ſtorm in the water round about, and ſhook ſome veſſels, that lay at a diſtance, ſo as to make thoſe who ſtood upon the decks to ſtagger. And in the late ſea-fight between the *Engliſh* and *Dutch*, tho' the engagement happen'd very many leagues from the *Hague*; yet the report of the guns not only reached that place, but had ſo conſiderable an effect there, as to ſhake the very windows. And if there be a greater diſpoſition in ſome other bodies, than there is in glaſs windows, to receive impulſes from the air, they may be ſenſibly wrought upon by the noiſe of a ſingle piece of ordnance; as appears by a remarkable circumſtance mentioned by *Simon Pauli*, in his treatiſe of malignant fevers. He ſays, that a *Frenchman* having his arm mortified, they were obliged to take it off; after which operation, he lived eight days, very ſtrongly convulſed; that ſtanding with others by his bed-ſide, once when the great guns, whereof they took no notice, were fired from the king's ſhips; as every one went off, he clap'd his left-hand to his ſtump, and lamentably complain'd of pain there; ſo inſufferable was each ſingle exploſion to him; tho' the guns were at a great diſtance, and fired not upon or near the land, but from the ſea. And the commander of a man of war aſ-

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ſured me, that ſome men on board him, whoſe bones were broken, would ſadly complain of the torment they ſuffered by the ſhake of the enemies cannon; tho' they were too much accuſtomed to the report of great guns, to be offended by the bare noiſe. But if any one ſhould here ſuggeſt, that the water hath a ſhare in this communication; yet there is one kind of ſound, that muſt be confeſſed to be propagated by the air, as being made in it; and that is thunder, whoſe noiſe ſometimes ſo vehemently affects it, tho' without producing any ſenſible wind, that I have obſerved it to ſhake large ſtrong-built houſes, notwithſtanding the diſtance of the clouds, where the ſounds were firſt produced. Some ſea-captains too, who had ſailed to the *Indies*, told me they have had their ſhips ſo ſhocked with the thunder, as to diſplace their great guns. And as the celerity, wherewith ſounds are propagated thro' the air, is exceeding great; this effect is the leſs ſurprizing. *Merſennus* obſerves, that a bullet, ſhot out of a cannon, moves two hundred and forty yards in a ſecond; but I have more than once found, that ſounds paſs above four hundred yards in the ſame time, in *England*: tho' according to *Merſennus*, a ſound moves in that time, many yards more in *France*; which may poſſibly proceed from the different conſiſtence of the air in thoſe two places *. PHYSICS.

The great loudneſs of theſe ſounds, and the vehement percuſſion the air receives in their formation, may make it probable, that it was only the impetuoſity of the motion of the medium, which gave the ſhake to the windows and other ſolid bodies, made to tremble by the report of cannon or thunder; whilſt, perhaps, ſome of thoſe tremulous motions of ſolid bodies, might either depend upon, or be promoted by, the peculiar diſpoſition, that glaſs, and other bodies, endowed with elaſticity, may have to be moved by certain appropriate ſounds, more than they would be by others that were louder. If this be admitted, it will not render our inſtances improper to the preſent deſign; but only make ſome of them fit to be referred to another head. I ſhall, therefore, conclude this, with an odd obſervation of *Platerus*, which argues, that where there is a peculiar diſpoſition even in a firm body, it may receive conſiderable impreſſions from ſo languid a motion of the air, as is not ſenſible to other bodies of the ſame kind.

"A woman," ſays he, "taken ill of a ſudden, continually complain'd, "that ſhe ſhould be ſuffocated, tho' no ſigns of it appear'd. This "complaint of hers was always the greateſt, when any of the by-"ſtanders approached her, tho' ever ſo gently; for ſhe ſaid, that

* The reverend Mr. *Derham*, from a variety of accurate experiments, concludes that ſounds, at a medium, move 1142 feet in a ſecond; but that if the wind favours them, 'tis poſſible they may reach 1200; or if it be directly contrary, only 1120 feet in that time. See *Philoſ. Tranſ.* N°. 113. *p.* 2.

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PHYSICS. " ſhe at thoſe times felt a breath of air come upon her, as if ſhe " were inſtantly going to be choaked. She hardly remain'd in this " condition for two days, and then died." Our author adds, " I have " known other patients complain of the like breath of air, being rea " dy to ſtrangle them, when any one came nigh them; and always " found it a very bad ſign."

What is wanting in the bulk of ſome bodies, made up by their number.

3. *We undervalue the motions of bodies too ſmall to be viſible or ſenſible, notwithſtanding their numbers, which enable them to act in ſwarms.* Moſt men think of the effluvia of bodies, and their motions, as of finer ſorts of duſt, blown againſt the ſurfaces of bodies, and ſtopped in their progreſs, without penetrating into the internal parts. And according to this notion, it is no wonder, they ſhould have but faint operations upon them. But we ſhall judge otherwiſe, from conſidering, that theſe corpuſcles are, by their minuteneſs and figure, enabled to pierce into the innermoſt receſſes of the bodies they invade. For tho' we ſuppoſe each ſingle particle to be very minute; yet ſince we may imagine their numbers exceedingly great, it need not ſeem incredible, that they ſhould have a conſiderable operation upon others at reſt, or that have a motion too ſlow, to be ſenſible. If we turn up an ant-hill, we may ſometimes ſee ſuch an heap of eggs, as a few of thoſe inſects would not be able to draw after them; but if, in ſwarms, each lays hold of her own egg, it is ſurpriſing to ſee, how quickly the whole heap will be removed. And in thoſe caſes, wherein the invading fluid does not quite disjoin, and carry off any great number of parts; its operation may be illuſtrated by that of the wind upon a tree in autumn, whilſt it makes it ſelf a multitude of winding paſſages; bending ſome of the twigs, breaking off part of the fruit, and leaves, and variouſly altering the ſituation of others. And ſuppoſe we caſt two lumps, the one of ſugar, the other of amber, into a glaſs of water, they will both preſently fall to the bottom; and, tho' perhaps the amber may be lighter than the ſugar, yet the aqueous particles are far from being able to diſplace the amber, or any ſenſible part of it, or to exerciſe any viſible operation upon it; but the ſame minute particles of the liquor, being of a figure, which fits them to inſinuate, every way, into the pores of the ſugar, tho' the lump conſiſted of very numerous corpuſcles; yet the multitude of the aqueous particles to which they are acceſſible, is ſoon able to diſperſe them all; and carrying them along with themſelves, preſently render the whole lump of ſugar inviſible.

If, alſo, by a due degree of fire, we abſtract from running mercury four or five times its weight of good oil of vitriol, there will remain at the bottom, a dry and brittle ſubſtance exceeding white; and if upon this heap of mercurial and ſaline bodies, we pour a large quantity of water, and ſhake them together, the multitude of little white grains, which make up the maſs, will be pervaded, and manifeſtly altered, by the diſperſed corpuſcles of the water. But to inſtance

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ſtance in fluids; tho' it will eaſily be granted, that the flame of ſpirit of wine, is but a viſible aggregate of ſuch effluvia, ſwiftly agitated, as, without any ſenſible heat, would, of themſelves, inviſibly exhale; yet if we hold the blade of a knife, or a thin plate of copper, in the flame, we ſhall quickly diſcern, by the great heat acquired, what a number of corpuſcles muſt have been agitated by the fiery particles; if we ſuppoſe, what is highly probable, that they materially penetrated into the innermoſt parts of the metal. But, whether we ſuppoſe this or no, it will appear, that ſo yielding a body as the flame of ſpirit of wine, is able ſoon to act very powerfully upon the hardeſt metals. The like power may be farther eſtimated by the motions of animals; for tho' the animal ſpirits are minute enough to paſs thro' nerves, whoſe channels cannot be diſcerned; yet they ſerve to move, in various manners, the limbs and unwieldy bodies of the largeſt creatures. We might add, that in moiſt weather, the aqueous particles, ſwimming in the air, will enter, in ſuch great numbers, into the pores of a thick rope, as to make it contract, tho' ſuſpended with a great weight, tied at the end, to hinder it. PHYSICS.

But as to the determination of the motion of fluids, I obſerve, that tho' the wind, blown out at a ſmall bent tube of glaſs, call'd a blow-pipe, ſeems not to have any great celerity, in compariſon of the parts of flame; and is it ſelf of little force; yet when the flame of a lamp or candle is directed by it, ſo as to beat upon a body, at a convenient diſtance, it may be made to melt ſilver, or even copper it ſelf; which yet may be kept for many hours unmelted, in a red-hot crucible, or the flame of the lamp or candle, unaſſiſted by the blaſt. And if we can ſo contrive it, that a flame does not only touch the ſurface, but intermingle with the ſmaller parts of a body, it will then have a far more powerful operation. For tho' a pound or two of tartar may require ſome hours to calcine it to whiteneſs, if the flame have immediate acceſs, only to the outward parts; yet it will be calcin'd in a very ſmall part of that time, if, mixing with its groſs powder, an equal weight of good ſalt-petre, the mixture be fired and kept ſtirring, that the parts of the kindled nitre may have acceſs, at once, to very many parts of the tartar. And by a little artifice, nitre it ſelf may, without tartar, be ſpeedily reduced to a calx, not unlike the former. The load-ſtone is acknowledged to act by the emmiſſion of inſenſible particles. For tho' iron and ſteel be ſolid bodies, and magnetic effluvia corpuſcles ſo very minute, as readily to get in at the pores even of glaſs itſelf; yet, entering the ſteel in ſwarms, they may operate ſo violently on it, as to attract above fifty times the weight of the magnet. For to theſe I rather aſcribe magnetical attraction and ſuſpenſion, than to the preſſure of the ambient air; becauſe I have found on trial, that ſuch a preſſure is not abſolutely neceſſary to magnetical operations. And farther, as to the power of magnetical effluvia upon iron, I took filings of iron freſh made, that the

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PHYSICS. the virtue might not be diminiſhed by ruſt, and having laid them in a little heap upon paper held level, I applied to the lower ſide of it, juſt beneath the heap, the pole of a vigorous load-ſtone, whoſe emiſſions diffuſing themſelves thro' the metal, manifeſtly alter'd their appearance, and produced many erect aggregates of filings, placed one above another, like little needles: and as theſe needles ſtood erected upon the flat paper, ſo they would run to and fro, according as the load-ſtone, which was held underneath, moved one way or the other; and as ſoon as that was taken away, all this little ſtand of pikes would *fall* again into a confuſed heap.

There are two principal ways of explaining the change of water into ice, either of which affords a notable inſtance to the preſent purpoſe. For the particles of water, and much more the corpuſcles of cold, are confeſſed to be ſingly too ſmall to be viſible; and their motions are not ſaid to be ſwift, but rather judged ſlow; yet theſe, by their number, produce ſo forcible a motion in glaciation, as to break bottles of glaſs, earth, or metal: and the expanſive endeavour of freezing water, is not only able to do this, but to perform ſo much greater things, that my trials have made me ſometimes doubt, whether any thing in nature, except kindled gun-powder, moves bulk for bulk, more forcibly, tho' the motion ſeems to be very ſlow.

The propagable nature of motion.

4. *We are not ſufficiently aware of the propagable nature of local motion, thro' different mediums and ſolid bodies.* There are four principal occaſions, on which, I have obſerved, men uſually think the communication of motion much more difficult, than indeed it is.

There are many, who, obſerving how ſome bodies, which hit againſt ſuch others as are hard, uſually rebound, eaſily perſwade themſelves, that motion can ſcarce be tranſmitted thro' them: but tho' in many caſes, the progreſſive motion be either inconſiderable or not ſenſible, yet the impulſe may make a conſiderable impreſſion, and be communicated to a great ſhare of the particles of that matter, whereof the ſolid conſiſts; as we ſee in ſtriking a timber-tree at one end, the motion may become ſenſible at the other. And tho' bell-metal be a very hard body, yet its ſolidity hinders it not from being ſenſibly affected by a weak motion, as may be made appear, by gently paſſing a pin along a part of the edge of a bell, which communicates to the whole a vibrating motion, and cauſes ſound, as will be audible for ſome time: ſuch a ſtroke alſo upon it with the like ſmall inſtrument, will have the ſame effect. Now, if ſound conſiſts in the undulating motion of the air, and ſo, in our caſe, requires a vibrating motion in the ſonorous body to impart it, we muſt grant a wonderful propagation of it in ſolid bodies themſelves; ſince the point of a pin gently ſtriking a part of a very ſolid metal, no bigger than itſelf, cou'd thereby produce a ſenſible motion, and that ſeveral times circulated to millions of parts equal to it in bulk, and much exceeding it in hardneſs. And what ſhews, that even ſoft and yielding bodies, faintly

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faintly moved, have a power of putting ſuch hard ones into motion, I found almoſt the like effects upon paſſing the pulp of my finger, a little way, along the lower part of a bell. As to the propagation of motion in ſolid bodies by heat, it greatly depends upon particular textures of the bodies. For heating a piece of glaſs, or a fire-ſtone, I could, without any inconvenience, hold my naked hand upon parts very near thoſe that were fired: but if one end of a rod of iron be made red-hot, the heat of that end will be ſo propagated towards the other, as to offend the hand at ſeveral times the diſtance. PHYSICS.

'Tis obſervable in many buildings, that a ſtamp of the foot, or bare treading in one room, will have a ſenſible effect in moſt of the others: and it often happens, that by the haſty ſhutting of a door, the whole houſe is made to tremble; whence we may argue, that, even amongſt ſolid bodies, motion made in one place may be readily propagated to many others. And if the ſudden impulſe, and compreſſion of the air made by a door, ſuppoſed to be haſtily ſhut, hath any conſiderable ſhare in the effect, this phenonemon will ſerve to ſhew the efficacy, even of ſuch a motion of a fluid body, as we cannot directly feel, upon ſeveral large ones that are firmly connected. In earth-quakes, which are ſuppoſed to proceed from the exploſion of ſubterraneous exhalations, the tremulous motion ſometimes extends very far beyond the places, where the exploſions were made. And, tho' *Seneca* confines the extent of earth-quakes to two hundred miles, yet later obſervations ſhew them to reach much farther. *Joſephus Acoſta* affirms, that in the kingdom of *Peru*, in the year 1586, an earth-quake ſpread along the ſhore of the pacific ſea, 160 leagues; and adds, that ſometimes it has in thoſe parts run on from ſouth to north 300 leagues. And in the year 1601, eminent writers relate a much larger earth-quake to have happened, reaching from *Aſia* to the *French* coaſt; and, beſides ſome *Aſiatic* regions, it ſhook *Hungary*, *Germany*, *Italy*, and *France*, that is, a great part of *Europe*. And if it be true, that it laſted not much above a quarter of an hour, 'tis the more likely, that this earth-quake ſhook great tracts of land beyond thoſe places to which the fired matter, paſſing from one cavity to another, could reach in ſo ſhort a time; for in trains of gun-powder, the fire does not run on near ſo ſwiftly as one would imagine. I my ſelf, alſo, have ſeen and felt the effects of a ſmall, harmleſs earth-quake, near *Oxford*, which extended many miles in length.

But it appears to how great an extent a motion, excited in a very narrow compaſs, may be propagated thro' different mediums, by the relation of *Famianus Strada*, who giving an account of a work, contrived to keep the city of *Antwerp* from being reliev'd in a ſiege, by the river *Scheldt*, tells us the effects of a floating mine, contrived to deſtroy it, in theſe words: "On a ſudden, the fatal ſhip burſt, with "ſuch an horrid craſh, as if the very ſky had rent aſunder, heaven "and

PHYSICS. " and earth had charged one another, and the whole machine of the " globe had trembled. For the ſtorm of ſtones, chains and bullets, " being caſt out with thunder and lightning, there followed ſuch a " ſlaughter, as no man could have conceiv'd. The caſtle on which " the infernal ſhip fell, the pile-work of the bridge of St. *Mary*'s " fort, that part of the naval bridge next the caſtle, ſoldiers, ma- " riners, commanders, cannons, armour, and arms, all ſwept away by " this furious whirl-wind, toſſed into the air, and diſperſed as wind " ſcatters the leaves of trees. The *Scheldt*, prodigiouſly gaping, was " firſt ſeen to diſcover its bottom, then ſwelling over its banks, roſe " above the ramparts; and huge ſtones, thrown out to above a mile's " diſtance, were there found ſtruck deep into the ground: the mo- " tion of the panting earth, extending its force above nine miles." Which if he means the miles of that country, or *Dutch* leagues, are 36 *Engliſh* miles.

But even the motion of a coach or a cart, will, at a conſiderable diſtance, make the buildings conſiderably ſhake: 'tis, therefore, the leſs ſurprizing, that in a calm night, the march of a troop of horſe may be felt by attentive ſcouts, at a great diſtance, by the ſhake of the ground; tho' perhaps the impulſe of the air, conveyed along the reſiſting ſurface of the earth, may principally contribute to the effect.

And let it be here obſerved, that in peculiarly diſpoſed bodies, and eſpecially, in organical ones, a very languid motion may have a far greater effect, than it could produce by a bare propagation of it ſelf. For it may ſo determine the motion of the ſpirits in the body it works upon, as to make multitudes of them act, as if they conſpired to perform the ſame motions: as when a tickliſh perſon, by having the pulp of one's finger paſſed gently along the ſole of his foot, or the palm of his hand, has various muſcles, and other parts of his body and face put into preter-natural or unuſual motions. And moſt men, by being lightly tickled with the end of a feather, or a ſtraw, within their noſtrils, have their heads and many parts of their bodies put into that violent commotion, wherein ſneezing conſiſts. And *I* remember, that having been, by a diſtemper, for ſome time deprived of the uſe of my hands; it more than once happened to me, that ſitting alone in a coach, if the wind chanced to blow a ſingle hair upon my face, the tickling it produced was ſo uneaſy, as to make me apprehend falling into convulſions, or a ſwoon, before I could get it removed by my ſervant.

There are others who cannot believe, that local motion, eſpecially if it be languid, ſhou'd be propagated thro' differing mediums, each of which, except that wherein the motion is begun, muſt, they think, either repel, or check and deaden it. To theſe I recommend the experiment of a watch heard to ſtrike, when incloſed in an exhauſted receiver. I have alſo perceived my own to ſtrike in my pocket, and felt the motion of the balance at the ſame time. But that motion

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tion may be propagated thro' different mediums, ſeems the more probable, by the ſhakings, often felt on beds, ſtanding in rooms cloſe ſhut, when loud claps of thunder are produced in the clouds. PHYSICS.

Agricola tells us, "that if an animal be thrown into a cave at *Viburg* in "*Carelia*, a country of *Scandia*, 'tis ſaid, an intolerable ſound breaks out "from it, with a guſt of wind; and that if any ſmall weight be caſt "into a cave there is in *Dalmatia*, tho', according to *Pliny*, it be done "on a calm day, yet a ſtorm, like a whirlwind, is immediately raiſed "thereby."

As ſome are unwilling to allow that motion can be conſiderably propagated thro' ſolid bodies; ſo, on the contrary, there are others, indiſpoſed to think, that it is near ſo propagable, as indeed it is, thro' fluid bodies; becauſe they preſume, that the parts of fluids eaſily giving way, will deaden the impulſe received by ſuch of them, as are firſt acted upon by the impelling body. And, there is yet another ſort of men, who cannot believe, that it ſhould be, thro' ſuch a medium, propagated to any conſiderable diſtance. But if luminous bodies act on our eyes, not by a ſubſtantial diffuſion of extremely minute particles, as the *Atomiſts* would have it, but by a propagated impulſe of ſome ſubtile matter, contiguous to the ſhining body, as the *Carteſians* maintain; it will be manifeſt, that a body exceeding ſmall may give a briſk motion to a portion of fluid matter, many millions of times bigger than it ſelf; ſince in a dark night, a ſingle ſpark of fire may be ſeen in different places, whoſe diſtance from it many thouſand times exceeds the diameter of the ſpark: not to mention the great diſtance, at which the flame of a ſmall taper may not only be ſeen, but appear larger, than near at hand. And if we compare the diameter of the planet *Venus*, which yet ſhines but with reflected light, with her diſtance from the earth, we may eaſily conclude, that the fixed ſtars, probably ſo many ſuns, which ſhine by their own native light, muſt impel a ſtupendous proportion of etherial matter, to be able, at that immenſe diſtance, to make ſuch vivid impreſſions, as they do, upon our eyes. And tho' fluid bodies do eaſily yield to ſolids, and thereby quickly deaden the motion of them; yet the motion being loſt, only in regard of the ſolid body, is not loſt, but tranſmitted, and diffuſed in reſpect of the fluid. Thus when a log of wood, or any ſuch body, ſpecifically lighter than water, is let fall into the middle of a pond, tho' its progreſs downwards be checked, and it is brought to reſt quietly on the ſurface of the water; yet its motion is not loſt, but communicated to the parts of the water, againſt which it firſt ſtrikes, and by thoſe to others, till at length the waves, produced on the ſurface, ſpread themſelves to the brinks, and would, perhaps, be farther expanded, if theſe did not hinder their progreſs. Whence we may learn, that, tho' the nature of fluid bodies requires, that their parts be actually diſtinct, and ſeparately moved; yet the particular corpuſcles, which compoſe them, being

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touched by ſeveral others; the new motion, produced in ſome of them, by an impelling ſolid, muſt needs make them impel the contiguous corpuſcles, and theſe, ſuch as lie next to them; and ſo the impulſe may be propagated to a vaſt diſtance: ſince, in a fluid body, the corpuſcles yield more eaſily to the impelling power; and being here almoſt balanced by others of the ſame fluid, a very ſmall force may ſuffice to impel them. Thus, tho' the braſs ſcale of a *balance*, ſeveral inches in diameter, may be ſuppoſed to outweigh many myriads of ſuch particles as compoſe water, wine, *&c.* yet, ſuch a ſcale being duly counter-poiſed with another, I have eaſily put it into various motions, only with the inviſible effluvia of a ſmall piece of amber. And if we conſider the inſtance of the concentric circles, made by the falling of a ſtone into ſtagnant water, we ſhall be the more eaſily perſwaded, that even in an heavy fluid, a motion may reach much farther, than men are uſually aware of, beyond the parts on which it was firſt impreſſed. An experienced navigator, who much frequents the coaſt of *Greenland*, and other northern regions, to fiſh for whales, aſſured me, he had not only often heard the ice, in breaking, make a more terrible noiſe, than the loudeſt claps of thunder with us; but that, ſometimes, when the ſea-water had undermined the foundation of mountainous pieces thereof, he hath known it ſuddenly fall into the ſea below, with ſuch violence, as to make a ſtorm, at a great diſtance off; and that, once, when he lay two leagues from the place where a ſtupendous maſs of ice fell, it raiſed the waves ſo high, as to waſh over the ſtern of his ſhip, with great danger to ſome of the men; and to ſink ſeveral of his ſhallops, that were riding near; tho' ſcarce any veſſels in the world were ſo fitted for rough ſeas as thoſe. The air, indeed, is a much thinner fluid than water, yet, becauſe we are apt to think it indiſpoſed to propagate motion far off, I muſt obſerve, that we are not to judge of it, by the effect it has on our ears, when the ſound is made in diſadvantageous places. For one, who hears a violin play'd on in an hung room, will think the ſound faint in compariſon of what it would appear, if the ſame inſtrument were touched in an arched roof without hangings; ſoft and yielding bodies being apt to deaden the ſound, which the figure and hardneſs of the vaulted chamber would reflect. So, when a man ſpeaks in the free air, we uſually take no notice of the motion of the air, beyond the place we are in; but if the place happens to have an echo, tho' at many times that diſtance from the ſpeaker, we may then eaſily take notice, that the motion of the air was carried on, and that with vigour, much farther than we ſhould otherwiſe have obſerved. And I have often thought, that, even by the better ſort of echoing places, we are not informed, to how great a ſphere the motion, which the air is put into by ſounds, may extend, where its diffuſion and force are neither hindered nor weakened by bodies, placed too near, or indiſpoſed to promote its operation. *Fromundus*, who being profeſſor of philoſophy at *Lovain*, in the year 16[illegible]

1627, might eaſily know the truth of what he relates, affirms, that at the famous ſiege of *Oſtend* in *Flanders*, the thunder of the great ordnance was heard above thirty *Dutch* leagues, or one hundred and twenty *Engliſh* miles. And that is yet more ſtrange, which he adds concerning the diffuſion of the ſound of a drum, which was perceived at ſea, twelve leagues off. To which may be added, concerning echoes, the notable relation in *Varenius*, of an obſervation made by *David Frælichius*, who, in the company of two ſtudents, had the curioſity to viſit the mountain *Carpathus*, eſteemed the higheſt of all in *Hungary*, and ſaid to be much more ſteep, and difficult of acceſs, than any of the *Alps*. This *Frælichius*, having related, with what difficulty he and his companions aſcended above that region of the air, where they met with clouds, and vehement winds, adds; "At this height I fired a gun, "which at firſt gave a report no louder than if I had broke a ſtick; but "ſome time after, we heard a long continued murmur, which fill'd all "the lower parts of the mountain, valleys, and woods. And deſcending "along the ſnow, which had long lain between the valleys, we again un-"loaded our gun, which made a more dreadful noiſe than that of the "largeſt cannon; ſo that I fear'd the whole mountain was going to tum-"ble: and this ſound continued for half a quarter of an hour, till it had "enter'd the innermoſt caverns, whence, the parts of the air crowding "each other, it was beat back; but for want of ſuch cavities at the top of "the hill, the ſound was at firſt inſenſibly reverberated, till coming lower "and nearer to the caves and valleys, it was more forcibly daſh'd againſt "them." PHYSICS.

5. *We ſeldom regard what the modification of the inviſible motion of fluids may perform, on the diſpoſed bodies of animals.* *The effects of the inviſible motion of fluids upon animal bodies.*

There is a peculiar aptitude required in thoſe animals, or ſome particular parts of them, which are to be ſenſibly affected by ſuch motions as we here mean; which would, otherwiſe, be too languid to produce any great effect.

It ſeems the leſs ſtrange, that continuing ſounds, and durable impulſes of the air, or other fluids, ſhould have a manifeſt operation on ſolid bodies, conſidering the multitude of ſtrokes, which may, in a very ſhort time, be given, by the parts of the fluid to the conſiſtent body. For tho' each of theſe, apart, would, perhaps, be too languid to have any ſenſible effect; yet frequent repetitions, by the ſucceſſive parts of the fluid, have a very great power: as may be argued from the ſwing given to pendulums by a very languid force; as alſo from the tremulous motion, imparted to the metalline ſpring of a muſical inſtrument, by the correſpondent one given to the air by another ſtring. *Scaliger* tells us a pleaſant ſtory of a *Gaſcon* knight, whom the ſound of a bag-pipe would preſently force to make water: and I know a very ingenious gentleman, upon whom the running of a tap has almoſt the like operation. The noiſe of an ungreaſed cart-wheel, the ſcraping of a knife, and ſome other ſuch acute ſounds, ſo affect ſeve-

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PHYSICS. ral parts of the head, as to ſet the teeth on edge. But theſe effects are much leſs conſiderable, than that producible on an ingenious domeſtic of mine, whoſe gums will bleed upon the noiſe of tearing brown paper. Sir *Henry Blunt*, in his voyage to the *Levant*, tells us, that he ſaw in *Grand Cairo*, a neſt of four-legged ſerpents, two feet long, black, and ugly, kept by a *Frenchman*, who, when he came to handle them, would run, and hide themſelves in a hole; but upon the muſic of his cittern, would all crawl out again, and *climb* up to him, till he gave over playing, when they ran away again. And a perſon of great judgment and integrity told me, that he, with many *European* merchants, had ſeen, in the *Eaſt-Indies*, the owner of ſome large tame ſerpents, taken by the common people there for a *Magician*, who by muſic could make them dance in ſtrange, frightful and very erect poſtures; or ſeem to ſleep, and, as it were, melt away with pleaſure, by particular parts of a tune. And according to *Kircher*, there is a great fiſh, in the *Streights*, between *Sicily* and *Italy*, much affected with a peculiar kind of tune, whereby mariners allure it to follow their veſſels. I will not affirm, there is any certainty in the famous tradition, of the lion's being terrified at the crowing of a cock; for a late *French* traveller affirms, that rowing along the brink of *Euphrates*, they were, for many hours in the night, terrified by lions that attended them, and were not at all afraid of the frequent crowing of the cocks, which chanced to be in the paſſage-boat. I might add, that many ſleeping perſons will be more eaſily awaked, being called upon by their own names, than by others, tho' uttered with a louder voice. I ſhall not inſiſt on that example of the operation of a ſound, afforded by the ſtarting of men, or larger animals, upon a ſurprizing noiſe; whereby the whole bulk of the animal is ſuddenly raiſed from the ground, which, perhaps, could not be done by the bare counter-poiſe of ſome hundreds of pounds; becauſe this ſeems to depend rather upon the loudneſs or acuteneſs of the ſound, than any determinate modification of it. But the moſt eminent inſtance of the efficacy of peculiarly modified ſounds upon diſpoſed bodies, is afforded us by what happens to thoſe who are bit by a *Tarantula*. For, tho' ſuch perſons will calmly hear ſeveral other tunes, yet when a peculiar one comes to be plaid, it will ſet them a dancing with a ſurprizing vigour; and this dancing will ſometimes continue for many hours, if the muſic ceaſes not. I know there are ſome, who queſtion the truth of the things related of theſe *Tarantati*; and I grant, that ſome fictions may have paſſed under the countenance of ſo ſtrange a truth. But, beſides the affirmations of learned men, I have received atteſtations hereof from an acquaintance, who, at *Tarantum* it ſelf, whence the inſect takes its name, ſaw many bitten perſons in their dances; and amongſt the reſt, a phyſician, on whom the tune, that fitted his diſtemper, had the ſame operation, as on the other patients. And *Epiphanius Ferdinandus*, who practiſed phyſic in *Apulia*, and *Calabria*,

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obſervation, ſeveral narratives of the effects of muſic upon the *Tarantati*, but invites any, who may doubt of the truth of ſuch narratives, to repair to him, at a fit ſeaſon; undertaking to convince them by ocular demonſtration. I have, alſo, my ſelf ſeen an ingenious perſon, who in *Calabria* or *Apulia*, was himſelf bitten by one of theſe venomous inſects; tho' the hurt was ſlight. Yet this, together with what he had ſeen in others more unhappily bitten, confirm'd what ſober writers affirm of the ſymptoms and cure of that poiſon. A very honeſt, and ſober muſician, hath, ſeveral times, affirmed to me, that he could, at pleaſure, by playing a certain tune, which wou'd not affect others, make a certain perſon weep, againſt her will. I might add, that when I have been taking phyſic, or am any thing feveriſh, the repetition of two verſes of *Lucan* ſeldom fails, as I have tried, of producing in me a chilneſs, almoſt like that, but fainter, which begins the fit of an ague: tho' I look not on this as a ſtrong proof of the phyſical efficacy of ſounds; becauſe thoſe two verſes having been emphatically read, when, ſeveral years ago, I lay ſick of a ſlow fever, and could not reſt, they made ſo ſtrong an impreſſion on me, that whenever I am under a diſcompoſure, like what then troubled me, thoſe verſes revive, as it were, that indiſpoſition in me.

'Tis the leſs ſtrange, that the vibrating motion of the air, which produces ſounds, ſhould produce ſuch effects upon diſpoſed organical bodies; ſince light it ſelf may have a notable operation, after the ſame manner. For the ſun-beams, by beating upon the eyes or faces of ſome, who come ſuddenly out of a ſhady place, preſently make them ſneeze; which is not done without a vehement motion of ſeveral parts of the body. And tho' colour be but a modification of light; yet it was anciently a practice, to preſent red objects to elephants, to make them more fierce. It is a familiar obſervation, that red clothes irritate turky-cocks: and *Valeſius*, a learned phyſician, tells us of a perſon, who, if he looked upon red objects, would not only have his eyes offended, but was alſo thereby ſubject to an effuſion of humours in the neighbouring parts.

The efficacy of unregarded motions in fluids, upon inorganical bodies.

6. *We ſeldom ſuſpect, what efficacy the inviſible motions of fluids may have on inorganical bodies, upon account of ſome determinate agreement, or relation betwixt a peculiar texture of the one, and the peculiar modification of the other's motion.* To manifeſt this by particular experiments, I ſhall begin with that common one, made with two uniſon-ſtrings of a muſical inſtrument; wherein a motion of the one, will ſuffice to produce a viſible motion in the other. But that the ſhake of the untouched ſtring may not be ſuſpected to be communicated to it, by the propagated motion of the inſtrument; I ſhall add, that a wire may, without another ſtring, be brought to tremble, by a determinate ſound, made at a diſtance, which produced but ſuch an impulſe of air, as could neither be ſeen, or felt by a by-ſtander; nor would communicate

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PHYSICS. cate any ſenſible motion to neighbouring ſtrings. It is true, that, in this caſe, the ſtring, in which the trembling was produced, being a ſingle, long, ſlender, and ſpringy body, faſtened at both ends to a ſtable one; it may ſeem unreaſonable to expect, that any thing like ſuch an effect ſhould be produced by the ſame cauſe, in bodies which do not appear ſo qualified. But as a certain degree of tenſion, is the principal qualification in order to this phenomenon, without which, all the others would be unavailable; perhaps in bodies, of a very different appearance from ſtrings, the various textures, connexions, and complications, that nature, or art, or both, may make of the parts, will bring them to a ſtate equivalent to the tenſion of the ſtrings of muſical inſtruments; whereby ſeveral of the mentioned parts will be ſtretched in the manner requiſite, to receive a vibrating motion from ſome peculiar ſounds: and, poſſibly, theſe trembling parts may be numerous enough to affect their neighbours, and make in the body they belong to, a ſenſible tremulous motion. I found upon trial, that if a large, hemiſpherical glaſs were conveniently placed; a determinate ſound, made at a convenient diſtance from the concave ſurface of the glaſs, would make it ſenſibly ring, as a bell, ſoon after it has been ſtruck. But this noiſe was the effect of a determinate ſound; for tho' the voice were raiſed to a higher tone, or if the ſound were made louder, the ſame effect would not enſue. And I have been aſſured, that one *Petterus*, a vintner at *Amſterdam*, could take the tone of a rummer-glaſs, and raiſing his voice into that tone, firſt make it tremble, and then burſt. I obſerved alſo, that large empty drinking-glaſſes of fine white metal, had, each of them, its determinate tenſion. For cauſing the ſtrings of a muſical inſtrument to be variouſly ſcrewed up, let down, and briſkly ſtruck, we found, that the motion of one ſtring, when ſtretched to a certain tone, would make one of the glaſſes ring, and not the other; nor would the ſound of the ſame ſtring, tuned to another note, ſenſibly affect the firſt glaſs, tho' perhaps it might have its operation upon another. We muſt not omit, that after we had found the tone proper to one of the glaſſes, having broken off part of the foot, the ſame ſound of the ſtring would no longer be anſwered by the veſſel; but we were oblig'd to alter the tenſion of the ſtring, to produce the former effect. A famous organiſt has aſſured me, that at particular ſtops of the organs, ſome ſeats in the church would tremble; tho' by his relation, I ſuſpected this to be effected chiefly by the greatneſs of the ſound: but I have ſeveral times ſince obſerved certain ſounds of an excellent organ to make, not only my ſeat in the church to tremble under me, but to produce an odd motion in the upper part of my hat, which I could plainly feel with my hands. And, what inclines me to believe that this effect depends upon the determinate tone, rather than upon the loudneſs of the ſound, is, that I have often felt ſuch a kind of motion in the upper part of my hat, upon pronouncing

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pronouncing ſome words in ordinary diſcourſe. Nor is it only in ſuch ſmall, and yielding bodies, as hats, and ſtrings, that ſounds, not boiſterous, may produce ſenſible effects; for if they be adapted to the texture of the body, to be work'd upon, they may excite motions in it, tho' it be either ſolid, or very bulky. An ancient muſician affirmed to me, that playing on a baſs-viol, in the chamber of one of his ſcholars, when he came to ſtrike a certain note upon a particular ſtring, he heard an odd kind of jarring noiſe, which he thought, at firſt, had been either caſual, or proceeded from ſome fault in the ſtring; but having afterwards frequent occaſion to play in the ſame room, he plainly found, that the noiſe was made by the tremulous motion of the caſement of a window, which would be made to tremble by a determinate ſound of a particular ſtring, and not by other notes, either higher or lower. To this inſtance, I ſhall add a ſecond, that, I confeſs, I was not forward to believe, till trial had convinced me of its truth; to which end, I took the muſician, who told me the ſtory, with me to the place he mention'd; which was an arch, and would not anſwer to all notes indifferently, when we ſtood in a certain part, but to a determinate note, which he told me was *ce fa ut*, a little flatted; to which it anſwered very well, and not ſenſibly to others: and even when I made him raiſe his voice to an eighth, as conſonant as thoſe two ſounds uſually are in all other caſes, the vaulted arch did not appear to us affected with it. He informed me too, that he had tryed in moſt arches about the city, and could find no ſuch peculiarity in them, as being reſonant to all notes and ſounds indifferently, that were ſtrong enough; and farther, that, as this arch, for a hundred years, has been obſerved to have this property, ſo an ancient and experienced builder informed him, that any vault, which was exquiſitely built, would peculiarly anſwer to ſome determinate note or other. PHYSICS.

Various bodies not at reſt, but in a ſtate of tenſion, &c.

7. *We look upon ſeveral bodies, as having their parts in a ſtate of abſolute reſt, when indeed they are in a forced ſtate, as of tenſion, compreſſion,* &c. This obſervation will, probably, ſeem paradoxical. For when an intire body of a ſolid conſiſtence, and uniform matter, appears to be moveleſs, we take it for granted, that its parts alſo are perfectly at reſt: yet ſome obvious phenomena will teach us, that its component corpuſcles may have various motions, and endeavours among themſelves. Thus when a bar of iron, having been well hammered, is newly taken off from the anvil; tho' the eye can diſcern no motion in it, yet the touch will readily perceive it to be very hot: and the briſk agitation of its ſenſible parts will become viſible, by pouring a liquor upon it. When the lath of a croſs-bow ſtands bent, tho' neither the eye, nor touch, perceive any motion, in the ſpringy parts, yet if the ſtring be cut, the ſudden motion, tending to reſtore it to the figure it had before, diſcovers an elaſticity, whence we conclude it was in a ſtate of compreſſion. And tho' the ſtring of a bent bow, likewiſe,

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PHYSICS. likewiſe, appears to be in a ſtate of reſt; yet if you cut it aſunder, the extremes will fly from one another forcibly enough to manifeſt, that they were before in a ſtate of tenſion. But becauſe the bow and ſtring were brought into a violent ſtate by human force, I ſhall add, that there are ſeveral bodies, on which no ſuch force appears to have acted, tho' they, alſo, are in a ſtate of violent compreſſion or extenſion, and under a ſtrong endeavour of the parts, which ſeem at reſt, to ſhrink or fly out. I have obſerved, that a glaſs, which ſeemed to have been well nealed, would, ſometimes, crack of its own accord; and the glaſs-men relate, that if they take their glaſſes too haſtily from the fire, they will be very apt to do ſo. I alſo cauſed a flat lump of a particular metalline glaſs, to be made three or four times as thick as an ordinary drinking-glaſs; which was ſo diſpoſed to ſhrink upon a ſmall degree of refrigeration, that before it was ſenſibly cold, it would crack, with ſuch a noiſe and violence, that parts of it, of a conſiderable bulk, flew to a great diſtance from one another. Having, to preſerve a particular liquor of moment, incloſed it in a ſtrong vial, with an exquiſite glaſs ſtopple, and ſet the veſſel upon the edge of a window, in a high and ſecure place, that it might not be moved; it continued there for above a year. The liquor was of ſuch a nature, that if any one had, tho' but for a moment, taken out the ſtopple, I cou'd eaſily have diſcover'd it. At length, as I was one day ſtudying quietly in my cloſet, at a conſiderable diſtance from the place where the vial ſtood, I heard a loud and briſk noiſe, almoſt like the report of a piſtol; and perceiv'd ſomething come rolling to my feet, which I found to be the thicker and larger part of the ſtopple of my vial, that of it ſelf had flown off; leaving the other part ſo ſtrongly and cloſely adjuſted to the neck, that I cou'd by no means force it out. There was not the leaſt ſhake made in the room to occaſion this; nor any body preſent but my ſelf. If you take a piece of red-hot copper, and hold it over a ſheet of white-paper, you will perceive numerous flakes to fly off, with a little noiſe, ſometimes as far as the edges of the paper; which flakes ſeem, from their brittleneſs and colour, to be parts of the metal vitrified by the fire, and afterwards by a too haſty refrigeration ſhrinking ſo violently, as to crack and leap from one another, like the contiguous parts of the ſtring of a viol, which breaks by the moiſture of the air. An expert artificer in metalline concaves told me, he uſually obſerved them to ſhrink upon refrigeration. And the like I have obſerved in iron of a great thickneſs, and purpoſely fitted to a hollow body of metal, which it would not enter when it was heated, tho' it would, when it was cold. But that metals may ſhrink, and do ſo with a very conſiderable force, appears from hence, that the ſame artificer, after he had made ſome large concaves of an unfit mixture of metals, and removed them carefully from the fire, leſt they ſhould cool too faſt, obſerved, that when they came to be farther refrigerated, they

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they would crack with a great noiſe. Another tradeſman, whom I often employ, complained to me, that having caſt a kind of bell-metal upon a very ſtrong ſolid inſtrument of iron, of a ſurface conſiderably large, tho' the metal was ſuffered to cool in a warm room, from about eight o'-clock on *Saturday* night, till ten or twelve on *Monday* morning, and was then conſiderably hot to the touch; yet, ſhrinking from the iron, which would not ſhrink with it, it crack'd in ſeveral places, with a noiſe, equal to the report of a piſtol; tho' the metal was an inch and a half, or two inches thick. And the ſame perſon ſhewed me a large cylinder of iron, about which a coat of bell-metal had been caſt ſome days before, on which there was a crack near one end, made by the coldneſs of the iron, though the thickneſs of the bell-metal exceeded an inch. Nor is it only in ſuch mixtures as bell-metal, which may be very brittle, but even in a metal malleable, when cold, that the like phenomenon will ſometimes happen; as I learn'd from another artificer, who affirmed to me, that having caſt a ring of braſs, about a cylinder of iron, he found, that when the metal began to cool, the parts ſhrunk from one another, ſo as to leave a crack, which he was obliged to fill with ſolder, quite croſs the breadth of the ring; tho' this was above an inch thick. PHYSICS.

Now, theſe experiments ſeem to teach, that a body may be brought into a ſtate of tenſion, as well by expanſion with fire, as by the action of an external agent; and this ſtate of contraction, and compreſſion, will be illuſtrated by a well-ſtrung bow. For, as that is brought to a ſtate of compreſſion by the force of the archer; ſo by the elaſtical force of the bow, the ſtring is brought into a violent ſtate of tenſion, as is evident by cutting it; for then both the bow will fly ſuddenly outwards, and the parts of the ſtring ſwiftly ſhrink from one another. And according to this doctrine, the effect of other bodies upon ſuch as are thus brought into, what men call, a preter-natural ſtate, is not to be judged barely according to vulgar conceptions, but with reſpect to this latent diſpoſition of the patient: for inſtance, tho' a ſlack ſtring of a violin, will not be hardened by the vapours of the air in moiſt weather; yet a neighbouring ſtring of the ſame inſtrument, tho' perhaps much ſtronger, being ſcrewed up, will be ſo affected with thoſe vapours, as to break with noiſe and violence. And ſo when one part of a piece of glaſs is made as hot as poſſible, without appearing diſcoloured to the eye, tho' a drop or two of cold water have no effect upon the other part of the ſame glaſs, yet if they touch the heated part, whoſe uſual extenſion is altered by the fire, which vehemently agitates the component particles, the glaſs will crack. Having met with ſeveral pieces of glaſs, which I had reaſon to think were of a texture or temper, very different from the ordinary ſort; I try'd whether ſome of them were not more brittle and elaſtic, than their thickneſs gave room to imagine: but in ſeveral the experiment

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PHYSICS. wou'd not ſucceed, eſpecially if their figure were inconvenient; yet with others I had very good ſucceſs; particularly with ſome ſhaped almoſt like the ſharper end of the neck of a receiver. For tho' theſe pieces of glaſs are much thicker than ſuch necks, or ſix times as thick as the uſual drinking-glaſſes, yet I ſeveral times, by obliquely ſcratching, or rather ſtroaking them on the inſide with the head or point of a pin, made them forcibly burſt to pieces in my hand. In which ſurprizing effects of ſo languid a motion, the matter of the glaſs ſeem'd to contribute, tho' much leſs than the texture it obtain'd by the peculiar way of ordering it in the fire and the air. *And if it* is poſſible to aſſign other cauſes of theſe phenomena, than ſuch as we have mention'd, it will not much concern us; for whatever the *latent* cauſe of the breaking of the bodies may be, the manifeſt circumſtances of them ſuffice to ſhew, that bodies, which, as to ſenſe, *are* in a natural ſtate of reſt, may be in a violent one, as to tenſion, and have, either upon the account of the texture of the parts among themſelves, or upon that of ſome ſubtile matter, or other phyſical agent, a ſtrong endeavour to fly off, or recede from one another. I might here alſo alledge, the relation of an honeſt experienced artiſt, whom I often choſe to deal with for precious ſtones. For, once conſidering a large lump of matter with him, which contained ſeveral ſtones, that he took for coarſe agats, and which were joined together by a cement, that in moſt places was harder than ordinary ſtones, and bore a better poliſh than marble, I obſerved to him, that there remained ſeveral large cavities in this cement, which ſeemed to have contained ſuch ſtones as now made part of the lump; upon which he informed me, that ſeveral of the ſtones grew whilſt they were lodged in thoſe cavities: and when I told him, that tho' I had been long of an opinion, that ſtones may increaſe after their firſt formation; yet I did not ſee how any ſuch thing appeared by thoſe we were now examining; he aſſured me, that theſe ſtones, after they were firſt formed, *really* tended to expand themſelves by virtue of ſome principle of growth, which he could not intelligibly deſcribe; but that they, being *lodged* in a cement, extremely hard, and, therefore, not capable of being forced to give way, their expanſive endeavour was rendered ineffectual, but not deſtroyed; ſo that when, afterwards, they came to be taken out of the cement, wherein they were bedded, having their ſides now no longer wedged in, they quickly expanded themſelves, as if it were by an internal, and violently compreſſed ſpring; and would preſently burſt aſunder, ſome into two, and others into more pieces; whereof he gave me ſome, declaring, he had taken up theſe ſtones himſelf, naming the place, which was not very far off; that all he had told me, was from his own repeated obſervation; and that I needed not ſuſpect the ſtrokes, employed to force the ſtones out of their beds, made them break: for beſides, that many of them, which, it ſeems, were not compreſs'd

preſs'd enough, remain'd entire; ſeveral of thoſe, which broke, were taken out, without offering them any ſuch violence, whereto their burſting could, with any probability, be aſcribed. Faint ſtrokes and attritions may produce more laſting and operative motions, among the inſenſible parts of compact and ſolid bodies, than would be readily imagin'd; for having often cauſed thin glaſs veſſels, and eſpecially urinals, to be cleaned with ſand and water, tho' they would not appear from hence to have receiv'd the leaſt injury, but continue entire perhaps for ſeveral hours; yet they wou'd afterwards break, of themſelves, with noiſe. But as others, thus cleanſed, have ſtill remain'd without flaw for a long ſeaſon; this cracking ſeems principally to depend upon the peculiar texture of the glaſs in particular veſſels, ariſing from an undue mixture of the ingredients, or a too haſty or unequal refrigeration of the parts of the metal.

Many effects ariſe from inteſtine motion.

8. *One principal reaſon why ſuch motions as we ſpeak of, are overlooked, is, that we ſcarce ever take notice but of thoſe motions of ſolid bodies, wherein one whole body drives away another, or at leaſt viſibly hits againſt it; whilſt many effects proceed from the inteſtine motions, produced by the external agent, in, and among the parts of the ſame body.* This obſervation is likely to be more readily underſtood, than granted; and therefore, by way of proof, I ſhall offer the following experiments. We cauſed the moveable part in a large braſs ſtop-cock, to be nimbly turned backwards and forwards, in the contiguous cavity made to receive it: and tho' this motion of the key were made only by the bare hand, yet in a ſhort time the mutual attrition of the contiguous parts, made ſo briſk an agitation in the other, that the metal it ſelf ſwelled, ſo that the key could no more be turned, but remained fixed, as if it had been wedged in; whence to make it work as before, it was neceſſary, by cooling, to let it ſhrink a little, and ſo take off the mutual preſſure of the key, and the other part of the ſtop-cock. Nor is this to be looked on as a caſual experiment; for, beſides that it was made more than once, and is very agreeable to ſome other trials; a maker of ſuch inſtruments complained to me, that he was ſeveral times forced to intermit his work, and plunge his inſtrument into cold water, before he could, by grinding, adjuſt the key to the cavity it ought to fit. The next inſtance, is afforded us by the known experiment of paſſing a wet finger upon the orifice of the drinking-glaſs almoſt filled with water: for tho' the eye does not immediately diſcern any motion ariſing from the preſſure of the finger, made by one part of the glaſs upon another; yet, that a vibration is thereby produced, may be argued by the dancing of the water, the numerous drops that are made to leap quite over, and others that are toſſed up to a conſiderable height in the air. And that there may be conſiderable motions in the ſides of the glaſs, tho' it does not break, ſeems probable, becauſe a drinking-glaſs being artificially cut in a ſpiral

PHYSICS. line, inveſted and ſhaken, will vibrate up and down ſo, as to lengthen the glaſs above a quarter of an inch; yet, being ſet upright again, it will reſume its former figure, and appear entire.

That two pieces of iron rubbed againſt one another, will acquire heat, is not hard to be believed: but that an edge-tool of hardened ſteel, ſhould undergo a manifeſt and permanent change in its texture by friction, may not ſeem ſo likely; yet experience ſhews, that ſuch an one, by turning, and ſhaving off the parts of metal, may be brought to look of a bluiſh and yellowiſh colour, and become ſo ſoft, as to be uſeleſs in its former capacity, till it be again artificially hardened. A famous jeweller told me, that when he poliſhes ſapphires, rubies, and ſome other ſorts of hard gems, upon his mill, they would ſeem, when the attrition had made them very hot, to be all on fire, like ſo many little coals; and that each of them had the light it afforded, tinged with the colour proper to the ſtone; ſo that the ruby gave a red light, the ſapphire a blue, *&c.* And a ſkilful cutter of diamonds, and poliſher of gems informed me, that ſometimes when he poliſhed certain ſtones, eſpecially large rubies, but perhaps not thick, he could plainly perceive, that the ſtone gaped at and near the edge, as if it begun to be crack'd; which ſign admoniſhed him immediately, to ſlacken the motion of his mill, leſt the ſtone ſhould abſolutely burſt; which if it did not, he could perceive no flaw in it, when throughly cold, but it appeared as intire as ever. He added, that once having given too great a degree of heat to an oriental topaz, it crack'd upon the mill, ſo that one part quite ſeparated from the reſt, and ſpoiled the ſtone in the capacity of a gem. And a merchant, who bought a fine rough diamond in the *Eaſt-Indies*, valued at an hundred pounds, told me, that it ſpontaneouſly crack'd upon his hands, and became of little value, but as a rarity: and I cou'd not but wonder, to ſee ſo fair and hard a ſtone ſo oddly ſpoil'd with clefts. But the merchant, upon complaint of his loſs, learn'd from thoſe of more experience, that this was no ſuch ſtrange thing as he imagined; the like having happ n'd to others. Nor is it always neceſſary, that the matter which mak.s the parts of an inanimate body work conſiderably on one another, ſhould be either very hard, or impetuouſly moved. For, having ſome ſhort bars of fine tin, I reſolved to try whether, merely with my naked hands, I could not procure a conſiderable internal commotion among its parts; and accordingly laying hold on the two ends of a bar, I ſlow'y bent it backwards and forwards, till it broke in the midſt; when, I perceived, that the middle parts had conſiderably heated one another.

What uſe may be made of this experiment, as to the hidden cauſe of elaſticity, belongs not to this place; however, if the reſtitution of a ſpringy body, forcibly bent, proceeds only from the endeavour of the compreſs'd parts themſelves, to recover their former ſtate, one may take notice of the elaſticity, that iron, ſilver, and braſs acquire by ham-

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hammering, among the inſtances, that ſhew, what, in ſome caſes, may be done by a motion, wherein the parts of the ſame body are, by an almoſt unheeded force, made to act upon one another. The foregoing examples may alſo ſuffice, to ſhew how men are often unjuſtly prepoſſeſſed, that nothing conſiderable is to be expected from the motion of a body againſt another, unleſs the former makes a manifeſt percuſſion, or truſion of the latter. But, becauſe this prepoſſeſſion prevails eſpecially in caſes, where the body, which is to affect the other by friction or attrition, is it ſelf ſoft or yielding, I ſhall add a few inſtances to remove the prejudice. An artiſt, eminent for grinding of optical glaſſes, confeſſed to me, that ſometimes, when he went to poliſh his broader glaſſes, tho' but upon a piece of leather, ſprinkled with puttee, the friction did ſo heat, or otherwiſe agitate the parts of the glaſs, as to make it crack from the edge to the middle; which ſeemed the more ſtrange, conſidering what intenſe degrees of heat, glaſſes will endure without cracking, if the fire be but gradually applied; as this artiſt's glaſſes muſt have been gradually heated. But it may be worth inquiry, whether in this caſe, the whole work be performed by mere heat, or whether there intervene not a peculiar kind of motion, into which ſome bodies are diſpoſed to be put by a peculiar kind of friction, that ſeems fitted to produce in elaſtic ſubſtances ſuch a vibrating motion, as may have ſome conſiderable effects, not uſually produced by moderate heat, nor always by an intenſe one. The trembling of the parts of a drinking-glaſs, and the viſible vibration of the ſtrings of a baſs-viol, upon peculiar ſounds, may give countenance to this conjecture. And that in ſome bodies, ſuch a tremulous motion is producible, by rubbing them on ſo ſoft a thing as wool, or upon a piece of cloth, I found by this experiment. We caſt into a hollow veſſel, very ſmooth within, and of an almoſt hemiſpherical figure, ſeveral ounces of good melted brimſtone; and having ſuffered it to cool, and taken it out, the convex ſurface appear'd well poliſh'd; then, this lump, being briſkly rubbed in the ſame line, forwards and backwards, upon a cuſhion, in a ſtill place, I could, by holding my ear to it, and attentively liſtening, plainly hear a crackling noiſe made by the agitated parts, which continued in a briſk, and perhaps a vibrating motion for ſome time after the friction was ended. And that there may be a conſiderable commotion produced among the internal parts of bodies, by rubbing them againſt ſoft ones, I have often obſerved from the ſteams produced by rubbing good ſulphur upon my clothes: and have found the like effect from much harder, and cloſer bodies rubbed againſt one another. For having purpoſely rubbed two human *calculi* againſt each other, they quickly afforded a rank ſmell of ſtale urine. And diamonds themſelves will, by rubbing them upon woollen clothes, be made electrical; which ſeems to argue, that their parts are thereby ſet in motion. And that this commotion reaches to the internal parts, I am apt to think, becauſe I have a diamond, that,

PHYSICS. that, by well rubbing againſt my clothes, will, for a little while, ſhine in the dark; which is the ſame phenomenon I have produced in the king's large diamond, by giving it one briſk ſtroke with the point of a bodkin; where the light, which preſently appeared in the gem, ſeemed not referable to any thing ſo likely, as to the ſudden commotion made in the internal parts of it.

It deſerves to be inquired what kinds of modification of motion there are, and what effects they may have in the parts of ſolid bodies. For tho' the ſtones uſed by the *Italian* glaſs-men, are very hard, and have afforded me ſparks of fire by colliſion; yet by rubbing them a little, one againſt another, I found that ſuch an agitation was cauſed in their parts, as to make them yield fetid exhalations. And, poſſibly, glaſs owes the quality of emitting offenſive ſteams to the ſtony ingredient. And it is remarkable, that tho' ſo vehement an agitation of the parts, as is given to glaſs by heat, when made almoſt red-hot, does not cauſe it to emit odours; yet barely by dextrouſly rubbing two ſolid pieces one againſt another, thoſe fixed bodies will in a minute yield ſteams, ſenſibly and rankly fetid; tho' one would think theſe exhalations very much indiſpoſed to be forced off, ſince they were not expelled by the vehement fire, which the glaſs long endured in the furnace.

There are few things ſhew better, both how the parts of unorganiz'd bodies communicate their vibrating motions to one another, and how briſk thoſe motions are, than what happens upon ſtriking a large bell with a clapper. For tho' the ſtroke be immediately made, but on one part, yet the motion produced is propagated to the oppoſite one; and the ſucceſſive vibrations of the ſmall parts, even in ſo ſolid and cloſe a body, run many times round; as appears by the durableneſs of the noiſe, which ſeems plainly to proceed from the circularly ſucceſſive vibrations of the parts: for, unleſs they briſkly trembled themſelves, they can ſcarcely be fitted to give the air that motion, whoſe effect on the ear, we call ringing. And this motion of the parts of the ſounding bell may be farther argued from hence, that if the finger, or ſome other ſoft body, be laid upon it, the ſound will be checked, or deadened; and much more, if a broad ſtring, tho' ſoft, be tied about it. And not only an attentive ear may ſhew, that the ſound is produced by a motion, propagated circularly in the bell; but this vibration may ſometimes be alſo felt in the tremulous motion, communicated by the trembling parts of the bell to the finger warily applied. That this motion paſſes circularly from one ſide of the bell to the other, ſeems manifeſt by the great difference of ſound, obſervable in an entire bell, and a crack'd one; where yet all the matter, and the former figure are preſerved; only the continuity, which is neceſſary to the circulation of the tremulous motion, is hindred at the crack. The motion of the parts is alſo very briſk, ſince if a convenient ſized bell were bound about with a broad ſtring, and then

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then ſtruck with the uſual force, and which it would otherwiſe very well bear, that percuſſion would break it; a diſorderly check being given to the briſk motion of the parts, whereof ſome happening to be much more agitated than others, the force of their motion ſurmounts that of their cohesion, and ſo produces a crack. But becauſe great bells are not eaſily to be procured, or managed; I took that of a large watch, which had no handle put to it, except a little wooden bodkin, whoſe point we thruſt into the hole, uſually left in the middle of the baſis; and this ſerving to keep the bell ſteady, we placed in the cavity of it, near the edges, ſome black mineral ſand, or ſmall filings of ſteel, copper, or the like, which muſt not be too ſmall; and then ſtriking moderately with the key againſt the ſide of the bell, we obſerved, that whilſt it continued briſkly ringing, it made many of the filings to dance up and down, and ſometimes to leap and ſkip about; and having put a middle-ſized drop of water, near the lower edge of the bell, it was eaſy to make it viſibly tremble, and be, as it were, covered over with little waves, by a briſk ſtroke of the key on the oppoſite ſide. And this effect was more conſpicuous, when we placed a very large drop of water near the edge, on the convex ſide of a hand-bell, whoſe clapper was kept from touching the inſide of it. And to obviate their jealouſy, who, not having ſeen the manner of the above-metioned motion of the ſand, might ſuſpect it was produced by the impulſe, which the bell, as an intire body, received from the percuſſion made by the key; we ſeveral times forbore putting in the filings, 'till after the ſtroke had been given; which ſhews, that the dancing of the minute bodies proceeded from the briſk vibrations of the ſmall parts of the bell, which, at the ſame time, ſtriking the air alſo, produced a ringing ſound, that might very well, as it did, out-laſt the ſkipping of the filings; the exceedingly minute particles of the air, being much more eaſy to agitate, than the comparatively groſs and heavy corpuſcles of the powder: and this was the ſucceſs of our experiment in a bell, that little exceeded an inch and an half in diameter. PHYSICS.

Theſe obſervations I preſume will ſhew, that ſuch local motions, as are uſually, either paſſed over unregarded, or thought not worth the notice, may have a conſiderable operation, if not upon the generality of bodies, yet upon ſuch as are peculiarly diſpoſed to admit it; and ſo have a conſiderable ſhare in the production of ſeveral phenomena of nature, which are commonly referred to leſs genuine, and leſs intelligible cauſes.

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then

THE MECHANICAL PRODUCTION OF MAGNETISM.

SECT. I.

THOUGH the virtues of the load-ſtone are reckon'd among qualities the moſt occult, yet I ſhall attempt to ſhew, that ſome, even of theſe, may be introduced into bodies, by mechanical changes.

Iron may act as a load-ſtone.

And, 1. To ſhew that magnetiſm proceeds not from the ſubſtantial form of the load-ſtone; a piece of ſteel fitly ſhaped, and well excited, will, like a load-ſtone, have its determined poles, and with them point north and ſouth; it will attract other pieces of iron and ſteel, and, which is more, communicate to them the ſame kind of virtue, with it ſelf; and theſe faculties it poſſeſſes, not as ſlight and tranſient impreſſions, but ſettled powers, and may retain them for many years, if the load-ſtone, to which it was duly applied, were vigorous. Now, in a piece of ſteel or iron thus excited, it is plain, that the magnetic operations may be regularly performed, for ſucceeding years, by a body, to which the form of a load-ſtone doth not belong; ſince, as it had its own form before, ſo it retains the ſame ſtill; continuing as malleable, fuſible, *&c.* as an ordinary piece of the ſame metal unexcited: ſo that, if there be introduced a fit diſpoſition into the internal parts of the metal, by the action of the load-ſtone, the metal, continuing of the ſame ſpecies it was before, will need nothing, but the continuance of that acquired diſpoſition, to make it produce magnetical effects. And if this diſpoſition, or internal conſtitution of the excited iron be deſtroyed, tho' the form of the metal be not at all injured, yet its power of attraction will be aboliſhed; as appears, when ſuch an excited iron is made red-hot in the fire, and ſuffered to cool again.

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A load-ſtone, alſo, may eaſily, by ignition, be deprived of its power of ſenſibly attracting iron, and yet continue a true load-ſtone in other capacities; which, according to the vulgar philoſophy, ought to depend upon its ſubſtantial form: and the load-ſtone thus ſpoiled may, notwithſtanding this form, have its poles altered, at pleaſure, like a piece of iron.

Magnetical qualities may be mechanically produced, deſtroy'd, or alter'd, in the load ſtone and in iron.

And, tho' it be generally taken for granted, that in a ſound load-ſtone, never injured by the fire, not only the attractive power, but the particular virtue, which it hath, to point conſtantly, with one of its determinate extremes, to one determinate pole, flows immediately from its ſubſtantial, or at leaſt eſſential form; yet this form, remaining undeſtroyed by fire, the poles may be changed: for taking a very ſmall fragment of a load-ſtone, I found, that by applying ſometimes one pole, and ſometimes the other, to the poles of a very vigorous load-ſtone, I could change the poles of the little fragment; tho' by applying a larger piece, I was not able, in many more hours, than I employ'd minutes before, to make any ſenſible change of the poles. And this I hope may ſhew, that how unanimouſly ſoever men have deduced all magnetic operations from the form of the load-ſtone, yet ſome internal change of pores, or other mechanical alterations, or inward diſpoſition, either of the excited iron, or of the load-ſtone itſelf, will diſable, or enable a body to perform ſome determinate magnetical operations. I ſhall now add ſome farther particulars, to make it probable, that magnetical qualities may be mechanically produced or altered.

2. I have often obſerved in the ſhops of artificers, that, when well-tempered tools are heated by attrition, and apply'd to filings, or chips of ſteel, or iron, they will take them up, as if the inſtruments were touched by the load-ſtone: but as they will not do this, unleſs they are excited by friction, which makes a great commotion in the inner parts of the ſteel; ſo they retain not ſuch a vigorous magnetiſm, after they are grown cold again: as appears by the barely rubbing a piece of ſteel againſt the floor, till it gains a ſufficient heat; for whilſt it continues ſo, it diſcovers a manifeſt attractive power, but loſes it upon growing cold.

3. 'Tis, likewiſe, obſerv'd, that the iron bars of windows, by having ſtood very long in an erect poſture, may grow magnetical; ſo that if you apply the north point of a poiſed needle to the bottom of the bar, this will drive it away, and attract the ſouthern; and if you raiſe the magnetic needle to the upper part of the bar, and apply it as before, this will draw the northern extreme, which the other end of the bar repelled; probably, becauſe the bar is, in tract of time, by the continual action of the magnetical effluvia of the terraqueous globe, turned into a kind of magnet, whoſe lower end becomes the north-pole of it, and the other the ſouth.

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PHYSICS.

4. I have found, indeed, that, if a bar of iron, which has not ſtood long in an erect poſture, be but held perpendicular, the experiment will ſucceed; but then this virtue, diſplay'd by the extremes of the iron, will be ſo tranſient, that if the bar be but inverted, and held again upright, that end, which juſt before was the uppermoſt, and drew the north point of the needle, will now, being lowermoſt, drive it away; which will not happen to a bar, that has been for ſome years kept in the ſame poſition. So that, ſince length of time is requiſite to make the verticity of a bar of iron ſo durable, that the ſame extreme will have the ſame virtues, with regard to the magnetic needle, whether it be the upper, or the lower end of the bar; it ſeems not improbable, that by length of time, the whole magnetic virtue of this iron may be increaſed, and, conſequently, ſome degree of attraction acquired. And from hence, I ſhall endeavour to explain that ſtrange phenonemon, which is reported to have happened in *Italy*, the converſion of an iron-bar into a load-ſtone, whereof a piece was kept, amongſt other rarities, in the repoſitory of *Aldrovandus*. For, conſidering the greatneſs of its ſpecific gravity, the malleableneſs, and other properties, wherein iron differs from load-ſtone, I cannot eaſily believe, that by ſuch a way, as is mentioned, a metal ſhould be turned into a ſtone. Indeed, the ſtory is imperfectly told; the chiefeſt and cleareſt thing in it being, that at the top of the church of *Arimini*, a great iron-bar, placed there to ſupport a croſs of an hundred pound weight, was, at length, turned into a load-ſtone. But whether the reality of this tranſmutation was examined, and how it appeared, that the fragment of the load-ſtone, preſented to *Aldrovandus*, was taken from that bar of iron, I am not ſatisfy'd by the narrative. Therefore, conſidering the great reſemblance I have ſometimes ſeen in colour, beſides other manifeſt qualities, betwixt ſome load-ſtones, and ſome coarſe, or almoſt ruſty iron, I am tempted to think, that thoſe who obſerv'd this iron bar, when broken, to have acquired a ſtrong magnetical virtue, which they never dreamed, wou'd be communicated in tract of time, might be eaſily perſuaded, by this virtue, and the reſemblance of colour, that the iron was turned into load-ſtone; eſpecially, they being prepoſſeſſed with that *Ariſtotelian* maxim, whence the relator would explain this phenomenon, that ſimilar things are eaſily changed into each other.

5. But, leaving this as a bare conjecture, we find, that what virtue an oblong piece of iron may need a long tract of time to acquire, by help only of its poſition, may be ſoon imparted to it, by means of the fire; as is very obſervable in tongs, and ſuch like iron utenſils, which have been ſet to cool, leaning againſt ſome wall or other prop, that kept them in an erect poſture; which renders it probable, that the great commotion of the parts made by the vehement heat of the fire, diſpoſed the iron, whilſt it was yet ſoft, its pores lax, and parts more pliable, to receive much quicker impreſſions

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ſions from the magnetical effluvia of the earth, than it would have done, if it had ſtill been cold. And it is very remarkable, what different effects are produced, by the operation of the fire, upon two magnetic bodies, according to their reſpective conſtitutions. For, by keeping a load-ſtone red-hot, tho' you cool it afterwards in a perpendicular poſture, you may deprive it of its former power of attracting. But a bar of iron being heated, and ſet to cool perpendicularly, thereby acquires a manifeſt verticity. Of which differing events, poſſibly the reaſon is, that the peculiar texture and conſtitution which makes a load-ſtone, ſomewhat more than an ordinary ore of iron, its uſual ingredient, being ſpoiled by the violence of the fire, 'tis left in the condition of common iron, or iron-ore; whereas the fire ſoftens the iron itſelf, agitating its parts, and making them more flexible; and by relaxing its pores, diſpoſes it to be eaſily pervaded by the magnetical ſteams of the earth: from which it may, probably, receive its verticity: and this the rather, becauſe, I have often try'd, if an oblong load-ſtone, once ſpoiled by the fire, be thoroughly heated, and cooled either perpendicularly, or lying horizontally, north and ſouth, it may, as well as a piece of iron, treated in the ſame manner, be made to acquire new poles, or to change the old ones, at pleaſure. But whatever cauſes the different effect of the fire upon a ſound load-ſtone, and a bar of iron, it ſeems to ſtrengthen our conjecture, that magnetical operations may much depend upon mechanical principles.

I may add, that having brought a large piece of a certain kind of *Engliſh* oker to a convenient ſhape; though, till it was altered by the fire, it diſcovered no magnetical quality; yet after it had been kept red-hot in the fire, and ſuffered to cool in a convenient poſture, it was enabled to operate magnetically upon a poiſed needle.

6. The magnetical virtue in a body may be aboliſhed without deſtroying the ſubſtantial or eſſential form, and without ſenſibly adding, diminiſhing, or altering any thing, of the ſalt, ſulphur, and mercury, whereof chymiſts preſume iron and ſteel to be compoſed. For, it has been ſometimes obſerved, that the bare continuance of a load-ſtone itſelf, in a contrary poſition to that, which, when freely placed, it ſeems to affect, has either changed, or ſenſibly leſſened the virtue of it. And having a load-ſtone, whoſe vigour was very extraordinary, I lock'd it up in a cabinet; but when I had, ſome time after, occaſion to make uſe thereof, I found it ſo exceedingly decay'd, as to its attractive power, that I refuſed to employ it in any caſes of moment.

7. But this degeneration of the magnetical virtue, which may, in tract of time, happen to a load-ſtone, will, in a moment, be made by the help of that ſtone, in an excited needle. For a well-poiſed needle, being, by the touch of a good load-ſtone, brought to turn one of its ends to the north, and the other to the ſouth, may, by a con-

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PHYSICS. trary touch of the ſame load-ſtone, be deprived of the faculty it had of directing its determinate extremes, to determinate poles. Nay, by another touch, the needle may, preſently, have its direction ſo changed, that the end, which before pointed to the north, ſhall now regard the ſouth. And, to make it more probable, that the change of magnetiſm may be produced by mechanical operations, procuring ſome change of texture in the iron, I ſhall add, that if a rod of iron, by being heated, ſuffered to cool north and ſouth, and hammered at its ends, be very manifeſtly endowed with a magnetical virtue, this virtue will, in a moment, be deſtoryed, by two or three ſmart blows of a ſtrong hammer upon the middle of it *.

* Sir *Iſ. Newton* tells us, that, "Magnetiſm differs from gravity, becauſe magnetic attraction is not as the quantity of matter attracted; and becauſe ſome bodies are thus more attracted, others leſs, and a greater number not at all. Beſides, the magnetic force may be increaſed and diminiſhed in one and the ſame body, and it is ſometimes much greater in proportion to the quantity of matter than the power of gravity; and in going from the magnet decreaſes not in a duplicate, but nearly in a triplicate proportion of the diſtance." *Newton Princip.* p. 368.

Mr. *Whiſton* lately found, that a load-ſtone has both an attractive and a directive power, independent one of the other; whilſt iron touched by it has only the former, and will ſuffer ſteel filings to lie along, or ſtand perpendicularly to its ſurface, and not like the ſtone, direct them to certain angles, with reſpect to its ſuperficies and axis; that ſtones of ſmall ſize and virtue give as good a directive touch to needles, as the ſtronger and the larger; that the touch of the load-ſtone conſiderably diminiſhes the weight of the needle; one of 4584$\frac{1}{2}$ grains, loſing 2$\frac{1}{2}$ grains thereby, and another of 65726 grains, no leſs than 14 grains; that the abſolute attractive power of armed load-ſtones, is as their quantity of ſurface; that the load-ſtones attract needles which have been touched, and others which have not been touched, with equal force, at unequal diſtances; that both poles of a ſtone equally attract needles before the touch, upon which it is, that one pole begins to attract one end, and repel the other; tho' the repelling pole will ſtill attract upon contact, or at a very ſmall diſtance; that the attractive power of loadſtones, is in the ſeſqui-duplicate proportion of the diſtances of their ſurfaces, from the needle reciprocally; that the entire power of magnetiſm in this country, as it affects needles of a foot long, is to that of gravity, as 1 to 300; that the quantity of the magnetic power, accelerating the ſame dipping-needle, oſcillating in different vertical plains, is as the coſine of the angle made by thoſe plains, and the magnetic meridian taken on the horizon; and laſtly, that the times of oſcillation and vibration in dipping, and horizontal needles, equally good, is as their lengths directly; and the actual velocity of their points along their arcs always equal. See *Whiſton's Dipping-needle*, and *Philoſ. Tranſ.* paſſim.

SECT.

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SECT. II.

THE load-ſtone is ſo ſtrange a body, and its uſefulneſs to mankind already ſo great, that it were inexcuſable to neglect any phenomena that directly relate to ſo abſtruſe a ſubject. But in the preſent inquiry, I principally intend to make the load-ſtone rather the object, than the inſtrument of my experiments; by working on the very ſubſtance of the ſtone, not ſo much to advance or apply its faculties, as to weaken and deſtroy them, in order the better to underſtand them. Having, therefore, procured a conſiderable number of naked load-ſtones, moſt of them coarſe, differing in ſize, ſhape, colour, and countries; I made ſeveral trials upon them. *Experiments and obſervations upon the load-ſtone it ſelf.*

1. And, firſt, having made ſeveral load-ſtones glowing hot, and removed them from the fire till they grew cold again, I found a great diſparity of the viſible ſubſtance whereof they conſiſted, and the manifeſt ſtructure of the groſs parts that made them up. For ſome upon refrigeration, either fell aſunder of themſelves, or grew very brittle; others ſtill continued entire; ſome of them, being broken, looked like iron-ore; others being broken, after refrigeration, appear'd to conſiſt of flakes of ſeveral colours, lying parallel to one another: and others again, which, as I remember, were *Engliſh*, neither appear'd compos'd of any ſuch flakes, nor had their dark colours much changed by the operation of the fire, nor ceaſed to be ſolid bodies.

2. We could not, upon ſucceſſively burning ſeveral ſmall load-ſtones, diſcern any ſuch blue ſulphureous flame, as *Porta* in his natural magic relates himſelf to have ſeen, and judges to have been, as it were, the ſoul of the load-ſtone; upon the acceſs of which, he ſays, it loſt its magnetic faculty; which is moſt commonly true as to any conſiderable degree of the attractive power, tho' not of the directive faculty or virtue. But *Porta* might miſtake the ſmall flame, which is often emitted even by well-kindled and glowing charcoal, (on which ſort his load-ſtone was placed,) eſpecially when a little blown upon, for the exhaling ſoul of the load-ſtone; or elſe we may ſuppoſe, that his ſtone was more rich in unctuous moiſture than others.

3. The ſolidity of ſome *Engliſh* load-ſtones, led me, tho' I look'd upon them as a kind of iron-ore, to try whether they would not ſtrike fire. And having made ſeveral colliſions betwixt a rough piece, and a common ſteel; I found it was poſſible, with difficulty, to obtain ſome ſparks, tho' they ſeem'd ſmall; but briſkly ſtriking a large piece of ſmooth load-ſtone, with the edge of a ſteel hammer, we produced numerous ſparks, ſome of them of a ſurprizing bigneſs; for they

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PHYSICS. they were judged to exceed the ſize of thoſe uſually afforded by common flints.

4. For certain reaſons, I thought fit to try further, whether it were not poſſible, to make load-ſtones afford fire, without the help of iron or ſteel. I therefore choſe two ſolid pieces cut almoſt into the form of cubes; and found that many colliſions being made with them, eſpecially at the edges, there were produced, from time to time, but not frequently, ſome ſparks of fire; tho' neither ſo numerous, great or vivid, as thoſe when the ſteel was employ'd.

5. I have found that if an oblong load-ſtone, made glowing hot, be cooled perpendicularly, the lower extreme will thereby become its north pole: and now I add, that if ſuch a load-ſtone be refrigerated perpendicularly, upon the north extreme of a much ſtronger load-ſtone; the weaker ſtone will receive impreſſions, as if it were iron, and its lower extreme not be, as before, by the magnetic effluvia of the earth, made its northern pole; but it will be contrariwiſe animated by the pole of the load-ſtone, on which 'tis cool'd; ſo that the lower extreme of it will prove its ſouthern pole, briſkly attracting the north end of an excited needle.

6. By the like way of refrigeration, I alſo found, that a diſanimated load-ſtone may be reſtored, to ſome degree of attractive virtue; for I try'd that a ſmall load-ſtone, which, after being made red-hot in the fire, and cool'd perpendicularly upon the ground, was not able to take up a fragment of a needle; being again heated, and not only cool'd upon the pole of a ſtrong load-ſtone, but ſuffered to reſt on it a while after, ſoon grew vigorous enough, to take up what it could not move before.

7. I further obſerv'd, that tho' a load-ſtone which had once paſs'd the fire, wou'd not, by being made red-hot, have its body open'd and fitted, to take in plentifully the magnetical ſteams; would yet, like a wire of iron, acquire a new verticity from a vigorous load-ſtone; but not be in many hours ſo vigorouſly impregnated with magnetic virtue, if it were applied cold to the pole of the animating load-ſtone; as it would in a very ſhort time, if being glowing hot it were ſuffer'd to cool thereon.

8. It has been obſerv'd, that if a load-ſtone be made red-hot in the fire, it ſcarce retains any ſenſible attractive virtue; only it will be able, by being endowed with a magnetiſm from the earth, to drive away that pole of a needle which agrees in denomination with that pole of the load-ſtone, whereto it is applied. But this is not ſtrictly and univerſally true; for in ſome of our *Engliſh* load-ſtones, it has been remark'd, that ignition does not only leave them poſſeſs'd of a directive virtue, but alſo a conſiderable attractive power; ſo that they will ſuſtain a large weight of ſteel.

9. We

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9. We took three *Engliſh* load-ſtones, that appeared to be of a very compact ſubſtance; two of them not near half an inch in length; the other much greater, being about an inch long, and of a conſiderable breadth, yet of ſmall thickneſs: theſe were made red-hot in a fire of well-kindled charcoal; and when they thorowly glowed, we removed them, one after another, and ſoon ſet each upon a plate of ſilver; and ſeverally applying a capp'd load-ſtone to them whilſt yet red-hot, it ſeem'd manifeſt that the ſtone had not then ſo ſtrong an effect on them, as if they were not red-hot: but when they ceas'd to glow, tho' they were ſtill intenſely hot, the armed load-ſtone had a more powerful operation on them, by way of attraction, and ſuſtentation, than before; and, alſo, even than after the ſame ſtones were grown cold. PHYSICS.

10. This experiment was repeated with the two ſmaller magnets and the greater, with the like ſucceſs: and when they were grown cold, they did, notwithſtanding their having been twice ignited, diſcover ſome little magnetiſm, if apply'd to the end of a well-excited magnetic needle, nicely pois'd, with its centre of gravity upon the point of an ordinary needle. And, I found that the bigger of theſe three load-ſtones, after the firſt, if not alſo after the ſecond ignition, mov'd the magnetic needle more briſkly than one would have expected; and being thruſt into filings of ſteel, and then taken out, it carried up with it and ſuſtained a conſiderable number of them. Whence we may conclude, that in ſome load-ſtones of a very ſolid conſtitution, ſuch as this was; the magnetical virtue is more radicated or permanent, than in the generality of other magnetic bodies: this ſtone being the firſt wherein I obſerv'd, after I had thorowly ignited it, any attractive virtue able to take up filings of iron.

11. We took the ſame load-ſtone that was employ'd about the laſt experiment, and having again made it red-hot, in the fire, ſuffered it not to cool leiſurely in the air, as before, but quenched it, in a baſon of cold water; intending thereby to make a double variation of the experiment; firſt, by cooling it haſtily; and next, by cooling it in a fluid, vaſtly more denſe or ponderous than the air. The event of the trial was, that, upon the immerſion of the red-hot ſtone, there fell off ſome flaky matter, as if it had been ſcales of iron; and the ſtone, when cold, would not take up any filings of iron, as before it did; ſo that it appear'd to have loſt much of the virtue it ſo lately had; tho' it retain'd the power to move a well-pois'd needle, if it were held near, on either ſide of the point of it.

12. A black oblong load-ſtone, of a ſimilar ſubſtance, and weighing near three drams, having been made to glow in a fire of well-kindled charcoal, and to continue in that ſtate for ſome minutes; being weighed again as ſoon as it was cool'd, loſt about $\frac{1}{3}$ of a grain in weight, and much of its black colour.

13. A

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13. A lump of iron-ore, which looked almoſt like a white ſtone rather than common-ore, and about the bigneſs of two eggs; being apply'd, in ſeveral of its parts to an excited needle, did not appear to move it manifeſtly. But being afterwards made glowing hot, and kept ſo for a while, and then cooled; it did in thoſe parts, which ſeem'd by their new colour to abound with metalline corpuſcles, manifeſtly attract the north end of the needle, and this was try'd, both with a needle of our own touching, and by the mariners needle, whoſe *Flower-de-Luce*, the burnt ore manifeſtly drew.

14. A brick that had not been us'd, being ſaw'd length-ways into two equal pieces, and each of theſe being heated red-hot in the fire for a pretty while, and afterwards ſuffer'd to cool north and ſouth; thereby acquired a magnetical verticity: and with that end which in cooling reſpected the ſouth, faintly drew the *Flower de-Luce* of the mariner's needle; and with the other end, ſomewhat more vigorouſly drove it away, and a little attracted the other extreme of the needle.

15. We took a black load-ſtone, and having by degrees beaten it ſmall, without ſuffering it to touch any iron or ſteel veſſel, or inſtrument; we ſet aſide the groſſer grains, and upon ſome of the finer powder pour'd the ſpirit of common ſalt, which had, at firſt, a ſenſible operation upon it, by producing the fetid fumes, and making a kind of ebullition, as that menſtruum uſually does upon filings of iron or ſteel. Nevertheleſs, being kept for a night or two in digeſtion, it drew a high tincture; and tho' this was not at all, like the ſolution of iron in ſpirit of ſalt, green, but of a yellowiſh brown, not very remote from redneſs; yet a little of it being dropt into a freſh infuſion of galls, preſently turned it to an inky ſubſtance, which in ſome poſitions appear'd bluiſh, as a tincture of light ſolution of ſteel would have done. And having carefully made a ſolution of load-ſtone, with good *Aqua regia*, it was thought to be a fine ſolution of gold.

16. Having caus'd a weak load-ſtone to be heated red-hot, and afterwards to be beaten very fine, I digeſted ſpirit of ſalt upon it; which in a few hours acquir'd a tincture, almoſt like that of a troubled ſolution of gold. It ſtrongly reliſh'd of iron, and a little being dropt into the infuſion of galls, turned it immediately into an inky liquor. Part of this ſolution, being gently evaporated, grew thick like an extract, but did not ſeem diſpos'd to ſhoot into cryſtals; yet another part of it, precipitated with the ſalt of tartar, much like a ſolution of vitriol; and another with ſpirit of fermented urine, gave a large yellowiſh red precipitate.

17. A

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17. A red mineral of a conſiſtence between ſtony and earthy, was by me judged to be a kind of iron-ore, tho' having powder'd ſome of it, I could not find that a good load-ſtone would attract any part thereof; I, therefore, caus'd this red powder, wetted with linſeed oil, to be kept, for about two hours, glowing hot, in a crucible; by which means it was turn'd blackiſh. This dark-colour'd powder being taken out, and ſuffer'd to cool, would readily adhere to the ſame load-ſtone, almoſt as if it had been a heap of filings of iron. But the operation of the fire, perhaps, contributed as much as the linſeed oil, to this change: for, a parcel of the red powder being kept ignited in a crucible, without the liquor, afterwards appeared magnetical. PHYSICS.

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THE MECHANICAL PRODUCTION OF ELECTRICITY.

THAT it is not neceſſary to make electrical attraction the effect of a quality, flowing immediately from a ſubſtantial form, but rather, of a material effluvium, iſſuing from, and returning to, the electrical body, appears from ſeveral particulars obſervable in ſuch bodies, and their manner of acting.

The hypotheſes advanced to ſolve the phenomena of electricity.

Different hypotheſes are advanced to ſolve the phenomena of electrical attraction. The firſt is that of the learned *F. Cabeus*, who thinks the drawing of light bodies by amber, *&c.* may be accounted for, from ſuppoſing, that the ſteams, which iſſue out of ſuch bodies, diſcuſs and expel the neighbouring air; which, after it has been driven off a little way, makes, as it were, a ſmall whirl-wind, becauſe of the reſiſtance it finds from the remoter air, which has not been affected by the electrical ſteams; and that theſe ſhrinking back ſwiftly to the electric body, do, in their returns, bring along with them ſuch light ſubſtances as they meet with in their way. And upon this occaſion I offer it to be conſider'd; whether by the gravity of the atmoſpherical air, ſurmounting the ſpecific gravity of the rarified atmoſphere about the amber, the attraction may not, in ſeveral caſes, be either cauſed or promoted. Another hypotheſis is that of Sir *Kenelm Digby*, and others: according to which, the amber by being chafed, is made to emit certain rays of unctuous ſteams, which, when they come to be a little cooled by the external air, are ſomewhat condenſed; and have loſt of their former agitation, ſhrink back to the body, whence they ſallyed, and carry with them thoſe light bodies, to which their farther ends happen to adhere, at the time of their retraction. And this way is employ'd alſo by the learned *Gaſſendus*, who adds, that ſuch electrical rays being emitted ſeveral ways, and conſequently croſſing one another,

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ther, get into the pores of the light body to be attracted, and, by means of their croſſing, take the faſter hold of it, and have the greater force to carry it along with them, when they ſhrink back to the body, whence they were emitted. PHYSICS.

A third hypotheſis is deviſed by *Des Cartes*, who diſlikes the ſolutions of others, chiefly becauſe he thinks them not applicable to glaſs, which he ſuppoſes unfit to yield effluvia, tho' it be an electrical body; and therefore attempts to account for electrical attractions, by means of certain particles, ſhaped almoſt like ſmall pieces of ribband, which he ſuppoſes to be formed of ſubtile matter, harboured in the pores of glaſs: but this is very doubtfully propoſed, by the author, and ſeems to be embraced upon a miſtake. He ſays, that electrical effluvia, ſuch as are ſuppoſed to be emitted by amber, wax, *&c.* cannot be imagined to proceed from glaſs; which ſuppoſition I grant is plauſible, but cannot allow it to be true. For as ſolid a body as glaſs is, yet if you dextrouſly rub, for two or three minutes, two pieces of it againſt one another, you will find that glaſs is able to emit very ſtrong effluvia.

But it is not neceſſary, that I ſhould here conſider, all that has been ſaid for and againſt each of the hypotheſes mention'd; ſince they all agree, that electrical attractions are not the effects of a mere quality, but of a material efflux from the attracting body; and all endeavour to ſolve the phenomena in a mechanical way, without having recourſe to ſubſtantial forms and inexplicable qualities, or ſo much as taking notice of the hypoſtatical principles of the chymiſts. It may, therefore, ſuffice, that I here mention ſome phenomena, which, in general, make it probable, that amber, *&c.* draw light bodies, by virtue of ſome mechanical properties, either of the attracting, or attracted bodies, or of both.

1. The firſt and moſt general obſervation is, that electrical bodies attract not, unleſs they be warmed; which, tho' it does not always hold, yet ſerves to countenance our doctrine of corporeal effluvia. For it is known, that heat, by agitating the parts of a fit body, ſolicits it to ſend out its effluvia, as is obvious in odoriferous gums and perfumes, which, being heated, emit their fragrant ſteams both farther, and in greater plenty, than otherwiſe they would. *That electrical bodies act mechanically.*

2. It has been obſerved, that amber, warmed by the fire, does not attract ſo vigorouſly, as if it acquires an equal degree of heat, by chafing: ſo that the modification of motion, in the internal parts, and in the effluvia, may, as well as the degree of it, contribute to the attraction. And the effect may often be promoted by employing both theſe ways ſucceſſively; as I manifeſtly found, by firſt warming amber by the fire, and preſently after chafing it upon a piece of cloth: as if the heat of the fire had put the parts into a general, but confuſed agitation; to which it was eaſy for the ſubſequent attrition to

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PHYSICS. give a convenient modification, in a body whoſe texture diſpoſes it to become vigorouſly electrical.

3. Another obſervation is, that electrical bodies require a poliſh, as well as attrition; and tho' I doubt whether the rule be infallible, yet weaker electrics require to be as well wiped, as chafed; and even good ones will have their operation promoted by the ſame means. For wiping is a kind of attrition, and frees the ſurface from what might choak the pores of the amber, or hinder the efflux of its ſteams.

4. It is likewiſe obſerved, that as tho' magnetical ſteams are ſo ſubtile, that they penetrate thro' all kinds of mediums hitherto known; electrical effluvia are, like thoſe of ſome odoriferous bodies, eaſily checked in their progreſs; ſince the interpoſition of the fineſt linen or ſarſnet, is ſufficient to hinder all the operation of excited amber upon a ſtraw, or a feather, placed ever ſo little beyond it.

5. It has been alſo obſerved, that the effects of electrical attraction are weakned, if the air be thick and cloudy; and eſpecially, if a ſouth wind blows; that electrics diſplay their virtue more faintly by night than by day, but more vigorouſly, in clear weather, and when the wind is northerly; and that thoſe bodies, which are but faintly drawn, when the weather is clear, will not be at all moved when it is thick and cloudy.

6. We have alſo obſerved, that ſeveral concretes, which are notably electrical, abound in a ſubtile matter, capable of being manifeſtly evaporated by heat, and rubbing. Thus, moſt reſinous gums, which draw light bodies, do alſo, being moderately ſolicited by heat, emit ſteams; pieces of ſulphur, upon due attrition, give a ſulphureous ſmell; and the piece of amber, which I moſt employ, and is ſomewhat large, and very well poliſhed, being rubb'd upon a piece of woollen cloth, will emit ſteams, manifeſtly ſcented of amber.

7. It agrees very well with what we have ſaid of the corporeal emanations of amber, that its attractive power will continue, after it has been once excited. For the attrition having cauſed an inteſtine motion in its parts, the heat thereby excited ought not to ceaſe, as ſoon as ever the rubbing is over, but to continue capable of emitting effluvia for ſome time afterwards, longer or ſhorter, according to the goodneſs of the electric, and the degree of the commotion made; all which, joined together, may ſometimes make the effect conſiderable: and by this means, on a warm day, I with a certain body, not bigger than a pea, but very vigorouſly attractive, moved a ſteel needle, freely poiſed, about three minutes after I had left off rubbing it.

8. It ſeems not impoſſible, that electrical effluvia ſhould infinuate themſelves into the pores of many other bodies, becauſe I have found them ſubtile enough to attract, not only ſpirit of wine, but that fluid, we call ſmoke. For, having well lighted a wax-taper, I blew out the flame, and when the ſmoke aſcended, in a ſlender ſtream, held

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held at a convenient diſtance from it, an excited piece of amber, or a chafed diamond, which would manifeſtly make the aſcending ſmoke turn out of its former line, and beat, as it were, againſt the electric; and this, if vigorous, would act at a conſiderable diſtance, and ſeem to ſmoke for a tolerable while after.

9. That this attraction depends not on any particular ſympathy between an electric, and the body whereon it operates, ſeems the more probable, becauſe amber attracts not only one determinate ſort of bodies, as the load-ſtone iron, and thoſe bodies, wherein it abounds, but draws indifferently all bodies whatſoever, placed at a due diſtance from it, provided they be minute or light. But I am yet in ſuſpenſe as to its attraction of fire; for, having applied a ſtrong electric, at a proper diſtance, to ſmall fragments of kindled matter, they were readily attracted, and ſhone, whilſt ſticking to the body; but looking attentively upon them, I found the ſhining ſparks to be cloathed with light aſhes, which, in ſpite of my care, had been already formed about the attracted corpuſcles, upon part of the fire's expiring; ſo that it remained doubtful, whether the kindled corpuſcles, whilſt totally ſuch, were attracted; or whether the immediate objects of the attraction were not the new-formed aſhes, which carried up with them the unextinguiſhed parts of the fire, that chanced to be lodged in them. But as for flame, our *Gilbert* delivers it for his own experiment, that an electric will not move the flame of the ſlendereſt candle. I have try'd it with a rough diamond, extraordinarily attractive; and was not ſatisfy'd, that it attracted the flame, as it viſibly did the ſmoke. But tho' this ſhould prove an exception to the rule, yet it may well agree with my hypotheſis; ſince the heat of the flame might diſſipate the effluvia, by means whereof the attraction ſhould be performed. The celerity alſo of the motion of the flame upwards, might render it very difficult for the electrical effluvia, to divert it from its courſe.

10. We have found, that a vigorous piece of amber will draw, not only the powder of amber, but larger fragments of it. And, as one contrary directs to another, ſo this trial ſuggeſted a farther; which, in caſe of ſucceſs, would probably argue that in electrical attraction, not only effluvia are emitted by the electrical body; but that theſe effluvia faſten upon the body to be drawn, in ſuch a manner, that the intervening viſcous ſtrings, which may be ſuppoſed made up of thoſe cohering effluvia, are, when their agitation ceaſes, contracted, or made to ſhrink inwards toward both ends, almoſt as a highly-ſtretched lute-ſtring, when permitted to ſhrink into ſhorter dimenſions. But the conjecture itſelf was much more eaſy to make, than the experiment requiſite to examine it. For we found it difficult to ſuſpend, excite and poiſe an electric, ſo that the faint force, wherewith it attracts light ſubſtances, ſhould procure a motion to its whole body. But, after ſome fruitleſs attempts with other electrics, I had recourſe to

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PHYSICS. to a very vigorous piece of poliſhed amber; and when we had, with the help of a little wax, ſuſpended it by a ſilken ſtring, we very well chafed one of the blunt edges of it upon a kind of large pin-cuſhion, covered with a coarſe black woollen ſtuff; and then brought the electric, as ſoon as we could, to reſt, pendulous at the bottom of the ſtring. And thus, at length, we found, that if, as ſoon as the ſuſpended electric was brought to ſettle freely, we applied to the chafed edge, but without touching it, the cuſhion, which, by reaſon of its rough ſuperficies and poroſity, was fit for the electrical effluvia to faſten upon, the edge would manifeſtly be drawn aſide by the cuſhion ſteadily held: and if this was ſlowly removed, that would follow it a conſiderable way; and when this body no longer detained it, 'twould return to the poſture, wherein it had ſettled before. And this power of approaching the cuſhion, by virtue of the operation of its own ſteams, was ſo durable in our amber, that by once chafing it, I was able to make it follow the cuſhion no leſs than ten or eleven times.

Electricity, producible by mechanical changes.

11. Other phenomena might be added of the ſame tendency; but, deſigning here to give only ſome experiments about the production of electricity, it will be ſufficient to relate how I have produced or deſtroy'd this quality in certain bodies, by means of alterations, which appeared to be no other than mechanical. And (1.) Having, with a very mild heat, ſlowly evaporated about a fourth part of good turpentine, I found, the remaining body would not, when cold, continue a liquor, but it hardned into a tranſparent gum, almoſt like amber, and proved electrical. (2.) By mixing two ſuch liquid bodies, as *Petroleum*, and ſtrong ſpirit of nitre, in a certain proportion, and then diſtilling them, till there remained a dry maſs, I obtained a brittle ſubſtance, as black as jet; with its ſuperficies, where it was contiguous to the retort, gloſſy, as that mineral is when poliſhed: and I found it farther reſemble jet, in having an electrical faculty. (3.) Having burnt antimony to aſhes, and of thoſe aſhes, without any addition, made a tranſparent glaſs, I perceived it manifeſt, when rubbed, a conſiderable electricity. And this is the more remarkable, becauſe, as a *Vitrum Antimonii*, which is ſaid to be purer than ordinary, may be made of the regulus of the ſame mineral, in whoſe preparation, a great part of the antimonial ſulphur is ſeparated, and left among the *Scoriæ*; ſo glaſs of antimony, made without addition, may eaſily be reduced to a regulus; a body not reckoned electrical. (4.) I made ſome glaſs of lead *per ſe*, which alſo was not deſtitute of an electrical virtue, tho' it had but a very languid one. And this glaſs might eaſily be wrought again to afford malleable lead, which was never reckoned among electrical bodies. (5.) Having warily diſtilled amber, by itſelf, that I might have an unmixed *Caput mortuum*, and continued the operation, till it had afforded a large proportion of phlegm, ſpirit, volatile ſalt, and oil, we carefully broke the retort, and took out the remaining matter in a lump, which, tho' it had quite loſt its colour, being

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being burnt black, and tho' grown ſtrangely brittle; yet this *Caput mortuum* was ſo far from having loſt its electrical faculty, that it ſeem'd to attract more vigorouſly than amber itſelf, before it is committed to diſtillation. And from the inſtances afforded by the glaſs of antimony, we may learn, that when the form of a body ſeems to be deſtroyed by analyſis, which diſſipates the parts of it, the remaining ſubſtance may yet be endowed with electricity. From the ſecond example, and from the common glaſs, which is electrical, we may alſo learn, that bodies, which are neither of them, a-part, endowed with electricity, may acquire that virtue in the compound ſubſtance, which they conſtitute. PHYSICS.

12. To theſe experiments, I ſhall add a ſurprizing phenomenon, which may help to make it probable, that electrical attractions need not be attributed to the ſubſtantial, or eſſential form of the attrahent; but may be the effects of unheeded, and fortuitous cauſes. That falſe locks of hair, brought to a certain degree of dryneſs, will be attracted by the fleſh of ſome perſons, I had proof in two beautiful ladies who wore them; for, at ſome times, I obſerv'd, that they could not keep them from flying to their cheeks, and from ſtriking there, tho' neither of them had occaſion for, or did uſe paint. When one of theſe beauties firſt ſhewed me this experiment, I turned it to a complement, ſuſpecting there might be ſome trick in it, tho' I afterwards ſaw the ſame thing happen in the locks of the other too; who gave me leave to ſatisfy my ſelf farther; and deſiring her to hold her warm hand at a convenient diſtance from one of thoſe locks taken off and placed in the free air, as ſoon as ſhe did this, the lower end of the lock, which was free, applied itſelf preſently to her hand. This ſeem'd the more ſtrange, becauſe ſo great a multitude of hairs would not have been eaſily attracted by an ordinary electrical body, which had not been conſiderably large, or extraordinary vigorous. Afterwards I enquired of ſome other young ladies, whether they had obſerved any ſuch thing; and one of them told me, ſhe had ſometimes met with theſe troubleſome locks; but that all ſhe could ſay farther was, that they ſeem'd to fly moſt to her cheeks, when they had been put into a ſtiff curl, and when the weather was froſty *.

13. Having

* Mr. *Stephen Gray*, found by trial, that a feather drawn thro' his fingers acquired a degree of electricity, and would be attracted by the finger when held near it; that a human hair, after having paſſed three or four times between his finger and thumb, would fly to his finger at the diſtance of half an inch; and that the hair of a dog's ear and threads of ſilk would do the like. His trials alſo ſucceeded in pieces of ribband of ſeveral colours, and half a yard long; ſo that the hand held at the lower end of any of them, would attract them at the diſtance of five or ſix inches. But if they imbibed the moiſture of the air, their electricity would be much weaken'd thereby; tho' in this caſe, the fire never fail'd to give them a ſtrong one. In ſhort, he found woollen, paper, leather, wood-

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PHYSICS. 13. Having moderately excited a large vigorous piece of amber, I held a downy feather ſo cloſe to it, that the neareſt part thereof was drawn by, and ſtuck faſt to it; the remoter parts continuing in their former poſture: then applying my finger to the erect downy part, it immediately left its poſture, and applied itſelf to my finger, as if that had been an electrical body. And whether I offered my nail, or the pulp of my finger thereto, or held it towards the right hand, the left, or directly over the hairs or feathers, which were near the *little* quill, they ſuddenly, and for aught that appeared, equally turn'd towards them, and faſten'd themſelves thereto. And to ſhew, that the ſteams, which iſſued out of my finger, were not neceſſary to attract theſe hairs, I applied to them, after the ſame manner, a little cylindrical inſtrument of ſilver, to which they bowed, and faſtened themſelves, as they had done to my finger; tho' the tip of this inſtrument was preſented to them in ſeveral poſtures. The *like* ſucceſs I had with the end of an iron key, and alſo with a cold piece of poliſhed black marble: and ſometimes the hairs ſo readily faſtened themſelves to theſe extraneous, and unexcited bodies, that I have been able to make one of them draw the feather from the amber itſelf. But it is to be obſerved, that this unuſual attraction happened, only, whilſt the electrical operation of the excited amber continued ſtrong enough to ſuſtain the feathers. For afterwards, neither the approach of my finger, nor that of the other bodies, would make them change their poſture; yet as ſoon as ever the amber was excited again by a little friction, the feather would be diſpoſed to apply itſelf again to the bodies mentioned. And leſt there ſhould be any peculiarity in that particular feather, I made trials with others, and found the experiment to anſwer in the ſame manner. I made the experiment alſo at different times, at ſome months interval, but ſtill with the like ſucceſs. And farther, I found the like ſucceſs, when, in place of amber, I ſubſtituted another electric, and particularly a ſmooth maſs of melted brimſtone.

wood-ſhavings, parchment, and gold-beaters ſkin, to be electrical, and that they not only came to the hand, or any other ſolid body, but attracted ſmall bodies to them, ſometimes at the diſtance of eight or ten inches. Some of theſe, alſo, appear'd luminous upon friction. See *Philoſ. Tranſ.* N°. 366. p. 104.

The late Mr. *Hauksbee*, diſcover'd a ſurprizing kind of electricity in glaſs. A tube of that metal he found, wou'd, when rubbed, variouſly attract pieces of leaf-braſs, at a conſiderable diſtance, and with greater force, the more the tube was heated by rubbing; tho' this it did differently, according to the different temper and conſtitution of the air. He alſo found that the effect ceaſed, or was deſtroy'd, upon exhauſting the air out of the tube, but that it return'd in a conſiderable degree, upon its re-admiſſion, without any new attrition. *Hauksbee's Experiments*, p. 53.

I

I alſo found, that a vigorous piece of amber, which I cauſed to be purpoſely turn'd, and poliſh'd for electric experiments, wou'd, in warm weather, manifeſtly retain the power of attracting for ſeveral minutes; and it has ſtirr'd a poiſed needle, a quarter of an hour after it had been chafed. This piece of amber, being firſt well rubb'd, we ſuſpended over a ſtraw, a feather, or other light body in a glaſs receiver, and preſently exhauſting the glaſs of air, we let down the amber till it came very near the ſtraw or feather, and perceived, in ſome trials, that upon the leaſt contact it wou'd raiſe them up, and in others, without touching, attract them. PHYSICS.

14. But the event of electrical experiments is not always ſo certain, as that of many others; being ſometimes much varied by ſeemingly ſlight circumſtances, and now and then by ſome, which are altogether over-looked. And it is not ſo certain, as many think, whether ſome particular bodies be, or be not electrical. For *Kircher* reckons cryſtal among thoſe gems, that have not the attractive power, we are ſpeaking of; yet I remember not, among all the trials I have made with native cryſtal, to have found any piece deſtitute of it. A late writer, alſo, reciting the electrics, reckoned up by *Gilbert*, and increaſing the number with ſome obſerved by himſelf, denies electricity to the cornelian, and the emerald. I the leſs wonder he ſhould do it to the former, becauſe I have my ſelf in vain tried to make any attraction with a piece of cornelian, ſo large and ſo fair, that it was kept for a rarity; yet with ſeveral other fine cornelians, I have been able to attract, very manifeſtly, ſome light bodies: and I uſually wear a cornelian, which is richly endowed with electricity. And as for emeralds, I have, indeed, ſeen a ſtone, which, tho' green, had a vigorous electricity: this, however, was not a true emerald, but, which is rare, a green ſapphire: and I learned of the jeweller, who cut it, that it was ſo far from having the ſoftneſs of an emerald, that he found it even harder than a blue ſapphire. Without, therefore, concluding any thing from this experiment, except, that the want of an electrical faculty might be thought a concomitant, rather of the peculiar texture of the emerald, than of its green colour, I proceeded to make trial with three or four true emeralds, and found them all ſomewhat, tho' not equally electrical: and tho' by this ſucceſs, I could not gain a new way to judge of true and falſe emeralds, yet the rule I hoped to have eſtabliſh'd in theſe, may be of uſe in eſtimating, whether diamonds be genuine or counterfeit. For tho' glaſs hath a faint electricity, that of diamonds is exceeding vigorous. And I do not remember to have met with any electric of the ſame bulk, more vigorous, than a rough diamond I have. But as it has been obſerved, that diamonds attract better whilſt rough, than after they are cut and poliſhed; this ſeems to contradict what we ſaid of other electrics, that they attract more vigorouſly, if the ſurface be made very ſmooth, than otherwiſe: but

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PHYSICS. the great rapidity, with which the wheels that ſerve to cut and poliſh diamonds muſt be moved, excites a great degree of heat in the ſtone; whereby, perhaps, it loſes its exhalable matter ſo plentifully, as to impoveriſh it: and, perhaps, alſo, ſome little change may be hereby made in its texture, which indiſpoſes it to emit ſuch effluvia, as are the inſtruments of electrical attraction. But as I willingly leave the matter of fact to farther trial; ſo I do the cauſe of it, in caſe that proves true, to farther *in*quiry.

THE

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THE MECHANICAL CAUSES OF PRECIPITATION.

BY precipitation, I here mean ſuch an agitation, or motion of an heterogeneous liquor, as makes the parts of it ſubſide in the form of a powder, or other conſiſtent body. And as chymiſts call the ſubſtance, which thus falls to the bottom of the liquor, precipitate; ſo we ſhall term the body, put into the liquor, the precipitant; that which is to be ſtruck down, the precipitable ſubſtance or matter; and the liquor, wherein it ſwims before the ſeparation, the menſtruum or ſolvent. When the fall of a body is procured by a precipitant, the operation is called precipitation, in the proper or ſtrict ſenſe: but when the ſeparation is made without any ſuch addition, or when the ſubſtance ſeparated from the fluid part of the liquor emerges, inſtead of ſubſiding, then the word is uſed in a more comprehenſive, but leſs proper ſenſe. *Precipitation, what.*

The very name of precipitation having, in its chymical ſenſe, been ſcarce heard of in the peripatetic ſchools, it is not to be expected, that they ſhould have given us the reaſons of the thing. And it is likely, that thoſe few *Ariſtotelians*, who have taken notice of this operation, would, according to their cuſtom on ſuch occaſions, have recourſe to ſome ſecret ſympathy or antipathy between the bodies, whoſe action and re-action appears in this proceſs. And thus ſome chymiſts aſcribe precipitation, either to a ſympathy betwixt the precipitating body and the menſtruum, which makes the ſolvent run to the embraces of the precipitant, and ſo let fall the particles of the body ſuſtained before; or to a great contrariety between the acid ſalt of the menſtruum, and the fixed ſalt of the oil, or ſolution of calcined tartar, which is the moſt uſual precipitant they employ. But I ſee not how either of theſe cauſes will reach to all the phenomena exhibited, *Its cauſe enquired into.*

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PHYSICS. exhibited, or give a true account of ſome of thoſe, to which it ſeems applicable. For firſt, in precipitations, wherein, what they call a ſympathy between the liquors, is ſuppoſed to produce the effect; this ſympathy does not ſhew ſuch an occult quality as is preſumed, but rather conſiſts in a greater correſpondence, as to bigneſs, ſhape, motion, and pores of the minute parts, between the menſtruum and the precipitant, than between the ſame ſolvent, and the body it before kept diſſolved. And tho' this ſympathy, rightly explained, may be allowed to have an intereſt in ſome ſuch precipitations, as let fall the diſſolved body in its priſtine nature and form, only reduced to minute powder; yet in the generality of precipitations, this doctrine will ſcarce hold: for in ſome that we have made of gold and ſilver, in proper menſtruums, after the ſubſiding matter had been well waſhed and dried; I found the powder to exceed the weight of the gold and ſilver put to diſſolve: and the eye it ſelf ſufficiently diſcovers ſuch precipitates not to be mere metalline powders, but compoſitions, conſiſting not of the combined ſalts alone, but of the metalline parts alſo; as may be concluded from the ponderoſity of ſeveral of them in reſpect to their bulk, and from their reduction to true malleable metals.

The other chymical way of explaining precipitations, may, in a proper ſenſe, be uſed on ſome particular occaſions; but I think it much too narrow, and defective, in general. For firſt, it is plain, that not only ſalt of tartar, and other fixed alkalies, precipitate moſt bodies, which are diſſolved in acid menſtruums; as in making of *Aurum fulminans*, oil of tartar ſtrikes down the gold out of *Aqua regis*; but acid liquors themſelves, in many caſes no leſs powerfully precipitate metals, and other bodies out of one another. Thus ſpirit of ſalt precipitates ſilver out of *Aqua fortis*; the corroſive ſpirit of nitre plentifully precipitates that white powder, whereof *Bezoardicum minerale* is made; and ſpirit, or oil of ſulphur precipitates corals, pearls, *&c.* diſſolved in ſpirit of vinegar. And I have ſometimes made a menſtruum, wherein, tho' there were both acid and alkalizate ſalts, yet I did not find, that either acid ſpirits, or oil of tartar, or even ſpirit of urine, would precipitate the diſſolved ſubſtances. And I have obſerved, both that ſalts of a contrary nature will precipitate bodies out of the ſame menſtruum; as not only ſalt of tartar, but ſea-ſalt, being diſſolved, will precipitate each other; and each of them apart precipitate ſilver out of *Aqua fortis*; and that, even where there is a confeſſed contrariety betwixt two liquors, it may be ſo ordered, that neither ſhall precipitate what is diſſolved by the other.

The mechanical ways of accounting for precipitation. But it will the better appear, that theſe chymical hypotheſes are inſufficient to ſolve the phenomena, if we proceed to obſerve the mechanical ways, by which precipitations may be accounted for. To precipitate, then, the corpuſcles of a metal out of a menſtruum, the

two

of the menſtruum in their motions; or to weaken the ſuſtaining power of the menſtruum, and thereby diſable it to keep the metalline particles ſwimming any longer: and this fall of the deſerted metalline parts often enſues the more eaſily, when the ſuſtaining particles of the menſtruum come to be too much weakened; that proving an occaſion to them, diſturbed in the former motion, which kept them ſeparate, to make occurſions, and coalitions among themſelves, whence their ſinking becomes the effect, of both ways of precipitation; as, on the other ſide, there are ſeveral occaſions, on which the ſame precipitant, that brings the ſwimming particles of the metal to ſtick to one another, likewiſe, by mortifying or diſabling the ſaline ſpirits, or other parts of the ſolvent, weakens the ſuſtaining power of that liquor.

From the gravity and bulk of the diſſolv'd body.

To conſider theſe two ways diſtinctly. The firſt more general cauſe of precipitation ariſes from ſuch a coheſion procured by the precipitant in the ſolution, as renders the compounded corpuſcles too heavy to be ſuſtained. That, in many precipitations, a coalition is made betwixt the ſmall parts of the precipitant, and thoſe of the diſſolved metal, appears by the weight of the precipitate, which, tho' carefully waſhed and dryed, often exceeds that of the diſſolved metal: for, if, having diſſolved ſilver in good *Aqua fortis*, you precipitate it with the ſolution of ſea-ſalt, in fair water, and from the very white precipitate waſh the ſalts; the remaining powder, being dryed and ſlowly melted, will look much leſs like a metalline body, than a piece of horn, whence it takes its name of *Luna cornea:* ſo conſiderable is the addition of the ſaline to the metalline particles. And, that part of ſuch additions is retained, in many caſes, appears to the eye; for if you diſſolve mercury in *Aqua fortis*, and into the filtred ſolution drop ſpirit of ſalt, ſalt-water, or an urinous ſpirit, you will have a very white precipitate; but if, inſtead of any of theſe, you drop in oil of tartar *per deliquium*, the precipitate will be of a brick, or orange colour. From which experiment, and ſome others, I would gladly perſuade phyſicians, that it is not indifferent, by what means the precipitation is performed. For, by reaſon of the ſtrict adheſion of many ſaline particles of the precipitant and the ſolvent, the precipitated body, notwithſtanding all the uſual ablutions, may have its qualities much diverſified by thoſe of the particles of the liquors, when fitted to ſtick very faſt to it. And hence there muſt happen a great difference between precipitations; as any one will think, who precipitates the ſolution of ſilver with copper, with ſpirit of ſal-armoniac, ſalt-water, oil of tartar, quick-ſilver, crude tartar, and with zink. And in the preceding examples, it is not all one, whether, to diſſolve mercury or ſilver, you employ the ſubtile diſtilled ſpirits of ſalt, or the

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PHYSICS. the groſs body, either in a dry form, or barely diſſolved in common water.

That, alſo, the bulk of a body may greatly contribute to make it ſink, or ſwim in a liquor, appears by obvious inſtances. Thus ſalt, or ſugar, being put into water, falls at firſt to the bottom, and lies there, notwithſtanding the air, that may be intercepted between its parts. But when, by the action of the water, it is diſſolved into minute particles, theſe are carried up and down with thoſe of the liquor, and ſubſide not. The like happens, when a piece of ſilver is caſt into *Aqua fortis*, and in many other caſes. On the other ſide, I have obſerved, ſome bodies, that had long ſwam in a menſtruum, whilſt their minute parts were kept from uniting in it, wou'd, afterwards, by the coalition of many of thoſe particles into bodies of a viſible bulk, coagulate and ſubſide. Thus, particularly, in urinous ſpirits, well dephlegmed, after they had, for a conſiderable time, continued in the form of a perfect liquor, numerous ſolid corpuſcles, joining together, ſettled at the bottom of the glaſſes, in the form of ſaline cryſtals. Having, alſo, long kept a very red ſolution of ſulphur, made with highly rectified ſpirit of urine; I obſerved, that, at length, the ſulphureous particles, forming into little concretions, totally ſubſided, and left the liquor almoſt colourleſs. And hence it appears proper to mention, among the ſubordinate cauſes of precipitation, the aſſociation of the particles of a diſſolved body with one another. If in what the chymiſts call precipitate *per ſe*, the mercury be indeed brought to loſe its fluidity, and become a powder, uncompounded with any additional body, it will afford us a notable inſtance to prove, that the coalitions of particles into cluſters of the ſame matter, will render them unfit for the motion requiſite to fluidity. For this odd precipitation by fire, wherein the ſame menſtruum is both the liquor, and the precipitate, being not all made at once, the corpuſcles, which firſt diſcloſe themſelves by their redneſs, are rejected by thoſe of the mercury, that yet remains fluid, as unable to accompany them, in the motions that belong to mercury.

And perhaps in ſeveral caſes, the corpuſcles of a diſſolved body may become unfit to be any longer ſuſtained in the menſtruum, tho' the precipitant adds very little to their bulk; or at leaſt much more to their ſpecific gravity, than to that. For in many ſolutions made of bodies by acid menſtruums, there are either generated, or extricated many ſmall aerial particles; and it will be eaſily granted, that theſe may be ſmall enough to be detained in the pores of the liquor, and remain inviſible there, conſidering what a multitude of aerial, imperceptible bubbles is afforded by common water, in our exhauſted receivers. And if the corpuſcles of the diſſolved body, have any little cavities fit to lodge aerial particles; theſe inviſible bubbles may make, with the ſolid corpuſcles they adhere to, little aggregates, much

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much lighter *in ſpecie* than the corpuſcles themſelves; and conſequently, if the precipitant conſiſt of particles, of ſuch a ſize and ſhape, as are fit to expel theſe little bubbles, and lodge themſelves in the cavities they before poſſeſſed, new aggregates will be produced, conſiſting of the corpuſcles of the diſſolved body, and the particles of the precipitant: and theſe aggregates, tho' they poſſeſs perhaps more room, than thoſe, whereof the aerial bubbles made a part, will yet be ſpecifically heavier than the former; whereby they may overcome the ſuſtaining power of the menſtruum. And farther, it is upon account of the ſpecific gravity of a body, and not barely of the action of the precipitant, that an aggregate of particles rather falls to the bottom, than riſes to the top. For tho' the agents, that procured the coalition, render the cluſter of particles of two unwieldy a bulk to continue in the liquor, as parts of it; yet if each of them be lighter *in ſpecie* than an equal bulk of the menſtruum; or if they ſo unite, as to intercept a ſufficient number of aerial bubbles between them, and ſo become lighter than as much of the menſtruum, as they take up the room of, they will not be precipitated, but emerge; as may be ſeen in the preparation of thoſe magiſteries of vegetables, where ſome high-coloured plants being made deeply to tinge the lixivium, wherein they are boiled, are afterwards, by the addition of alum, curdl'd, as it were, into coloured concretions, which being too large to ſwim, as they did before they united, and too light, in compariſon of the menſtruum, to ſubſide, mount to the top, and float there. An eaſier example, and more pertinent to this purpoſe, is afforded by diſſolving camphire in highly rectified ſpirit of wine, till the ſolution is very ſtrong. For tho' the camphire, when put, by lumps, into the ſpirit, ſunk to the bottom of it, yet when a large quantity of water, (which is heavier *in ſpecie* than the gum) was poured upon the ſolution, the camphire quickly concreted, and returned to its own nature, and ſoon after emerged and floated on the top of the mixed liquors. Theſe particulars I mention, as inſtances of precipitation, improperly ſo called. But, I muſt here take notice of a phenomenon, which ſometimes occurs in precipitations, and may at firſt ſight ſeem contrary to our doctrine. For it now and then happens, that after ſome drops of the precipitant have begun a precipitation, if the veſſel be ſhook, the matter already precipitated diſappears, and the ſolvent again becomes clear, as before the precipitant was put into it. But this phenomenon doth not contradict our theory. For, when this happens, tho' that part of the ſolvent, to which the precipitant reaches, is made unable to ſupport the diſſolved body; yet this quantity of the precipitant is but ſmall, in proportion to the whole bulk of the ſolvent. And therefore, when the agitation of the veſſel diſperſes the cluſters of particles looſely concreted, thro' the whole liquor; that greater part, to which the precipitant did not reach before, may well be looked

PHYSICS. looked upon as a freſh menſtruum, which is able to mortify or overpower the ſmall quantity of the precipitant, mingled with it, and ſo to deſtroy its late operation on the body diſſolved; by which means the ſolution returns to its former ſtate. Thus, precipitating a brick-coloured powder out of a ſtrong ſolution of ſublimate, made in fair water; the ſubſiding matter being laid to dry in the filtre, by which it was ſeparated from the water, would retain a deep, but ſomewhat dirty colour; and if, putting it into the bottom of a wine-glaſs, I poured upon it, either clear oil of vitriol, or ſome other ſtrong acid menſtruum, the alcalizate particles being diſabled and ſwallowed up by ſome of the acid ones of the menſtruum; the other acid ones would ſo readily diſſolve the remainder of the powder, that immediately the colour of it vaniſh'd, and the whole mixture appear'd a clear liquor, without any ſediment.

From weakening the ſolvent.

The other of the two principal ways, wherein precipitations may be effected, is by diſabling the ſolvent to ſuſtain the diſſolved body. There are many inſtances, wherein this may conſpire with the firſt way propoſed: but, notwithſtanding nature may ſometimes employ them both together; yet in ſome caſes they ſufficiently differ. For, in the former, the fall of the diſſolved body is chiefly cauſed by the additional weight, as well as the action of the external precipitant; but in moſt inſtances of the latter, the effect is produced, either without ſalt of tartar, or any ſuch precipitant; or by ſome other quality of the precipitant, more than by its weight, or at leaſt, beſides the weight it adds. This premiſed, I obſerve, that the general way laſt propoſed, contains ſeveral ſubordinate ways, which are more peculiar. And firſt, a precipitation may be made, if the ſaline, or other diſſolving particles of the menſtruum are rendred unfit for their former function, by particles of a precipitant, of a contrary nature. Thus gold, and ſome other minerals, being diſſolved in *Aqua regis*, will be precipitated with ſpirit of urine, and other ſuch liquors, abounding with volatile, and ſalino-ſulphureous corpuſcles, whereby they act; whence theſe ſalts themſelves, tho' caſt into a menſtruum in a dry form, will make the like precipitations: yet the volatile particles of urinous ſpirits, add much leſs weight than ſalt of tartar, to the little concretions, which compoſe the precipitated powder. Upon inſtances of this kind, chymiſts have built that antipathy betwixt the ſalts of the ſolvent, and thoſe of the menſtruum, to which they aſcribe almoſt all precipitations. In anſwer to which, farther than what has been already offer'd, I ſay, firſt, that ſome of thoſe menſtruums, to which the antipathy is attributed, do, after a ſhort commotion, friendly unite into concretions participating of both the ingredients. To ſhew this, I have dropt a clear ſolution of fixed nitre, inſtead of the uſual one of common ſalt, upon a ſolution of ſilver in *Aqua fortis*; when, the ſaline particles of the ſolvent, and thoſe of the precipitant will, for the moſt part, kind-

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ly form themſelves into ſuch cryſtals of nitre, as they were obtained from. But were this notion of the chymiſts true, it ought to be explained by mechanical principles. For, if the particles of the menſtruum, and thoſe of the precipitant, be ſo framed, that by the action of the one upon the other, there will be produced corpuſcles, too big and unwieldy to continue in the ſtate of fluidity, a precipitation *muſt* enſue: but if the conſtitution of the corpuſcles of the precipitating, and of the diſſolved body, be ſuch, that the precipitant, alſo, it ſelf, is a fit menſtruum to diſſolve that body; then, tho' there be an union of the ſalts of the precipitant, and the metal, and perhaps of the ſolvent too, yet a precipitation will not neceſſarily follow; tho' the ſaline particles of the two liquors ſeemed, by the heat and ebullition excited between them upon their meeting, to ſhew a great and mutual antipathy. To be ſatisfied in this particular, I diſſolved zink in an urinous ſpirit, and then put to it a convenient quantity of a proper acid ſpirit; but tho' a manifeſt conflict hence aroſe, yet the zink remain'd diſſolved in the mixture. And for an eaſier experiment to the ſame purpoſe, I diſſolved copper, calcined *per ſe*, or even crude, in ſtrong ſpirit of ſalt; and having gradually put to it a large quantity of ſpirit of ſal-armoniac, or fermented urine; tho' there was a great commotion raiſed, with hiſſing and bubbles, the copper would not precipitate; becauſe this urinous ſpirit will, as well as the ſalt, diſſolve the ſame metal; and it continued diſſolved, notwithſtanding their operation on one another; which operation, as well as their action upon the metalline corpuſcles, appears from hence, that the green ſolution, made with ſpirit of ſalt alone, will, by the addition of urinous ſpirits, be changed either into a bluiſh green; or, if the proportion of this ſpirit be very great, into a rich blue, almoſt like ultramarine. And from theſe two experiments, we may probably argue, that when the precipitation of a metal, *&c.* enſues, it is not barely on account of the ſuppoſed antipathy betwixt the ſalts; but becauſe the cauſes of that ſeeming antipathy do likewiſe, upon a mechanical account, diſpoſe the corpuſcles of the blended liquors to cohere, ſo as to be too unwieldy for the fluid part.

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Another way, whereby the diſſolving particles of a menſtruum may be rendred unfit to ſuſtain the diſſolved body, is, to preſent them another, on which they can more eaſily work. A notable example of this we have in the common practice of the refiners, who, to recover the ſilver out of lace, and other ſuch mixtures, diſſolve it in *Aqua fortis*, and then in the ſolution leave copper-plates for a night. But to make the experiment with expedition; as ſoon as I have diſſolved a convenient quantity of ſilver in *Aqua fortis*, I add twenty times as much of diſtilled, or rain-water; and then, in the clear ſolution, hang, by a ſtring, a clean piece of copper, which will be preſently covered with little ſhining flakes, almoſt like the ſcales of fiſh;

By preſenting another body to be wrought on, &c.

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PHYSICS. and these we can easily shake off, to make room for more. This may also illustrate what we formerly said, as to the subsiding of metalline corpuscles, when they unite in liquors, wherein, whilst dispersed in very minute parts, they swam freely. For here the little scales of silver seemed to be purely metalline, and there is no saline precipitant, as salt of tartar, or of urine, employed to make them subside. Upon the same ground, gold and silver, dissolved in their proper menstruums, may be precipitated with running mercury; and if a solution of blue vitriol be made in water, a clean plate of steel or iron being immersed in it, will presently be over-laid with a very thin case of copper, which after a time grows thicker; but does not adhere to the iron so loosely, as to be shaken off, as the precipitated silver may be from the copper-plates. And that in these operations, the saline particles may really quit the dissolved body, and work upon the precipitant, appears by the practice of the refiners lately mentioned; where the *Aqua fortis*, which forsakes the particles of the silver, falls to work upon the copper-plates employed about the precipitation, and dissolves so much of them, as to acquire the greenish blue colour of a good solution of that metal. And the copper we can easily again obtain, without salts, by precipitation, out of that liquor with iron; and that too, remaining dissolved in its place, we can precipitate with the tastless powder of another mineral. Besides these two ways of weakening the menstruum, a third is, by lessening or disturbing the agitation of the solvent. And, indeed, since we find by experience, that some liquors, when they are heated, will either dissolve some bodies, they would not touch when cold, or dissolve them more powerfully when hot than cold; it is probable, that what considerably lessens such an agitation of the parts of the menstruum, as is necessary to keep the dissolved body in the state of fluidity, should occasion it again to fall to the bottom. I could give several examples of the precipitating power of cold in slow operations; for there are several solutions, and particularly that of amber-grease, which remaining fluid all the summer, will subside in the winter. And the like may be sometimes much sooner observed in the solutions of sulphur, made in certain oleaginous menstruums; and I have now and then had some solutions, and particularly one of benzoin, made in spirit of wine, which surprized me with the turbidness they would acquire, upon a sudden change of weather to cold, tho' it were not in the winter season. Another way of weakening the menstruum is, by diluting or lessening its tenacity. Of this we have an instance in the magisteries of jalap, benzoin, and of several other resinous and gummy bodies, dissolved in spirit of wine. For by the affusion of common water, the menstruum being too much diluted, is not able to keep those particles in the state of fluidity, but must suffer them to subside, or make some parts emerge. Examples, also, of this kind,

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are afforded us by the common preparation of *Mercurius Vitæ*. For, tho' PHYSICS. in oil of antimony, made by rectifying its butter, the ſaline particles are ſo numerous, and keep ſo cloſe to one another, as to be able to ſuſtain the antimonial corpuſcles they carried over with them in diſtillation, and retain them, with themſelves, in the form of a liquor; yet when by the plentiful affuſion of water, thoſe ſuſtaining particles are ſeparated, and removed to a diſtance from each other; the antimonial corpuſcles, and the mercurial, if any ſuch there were, being of a ponderous nature, will eaſily ſubſide into that emetic powder, which when waſh'd, is called *Mercurius Vitæ*.

But here, to ſhew how much precipitations depend upon the mechanical textures of bodies; tho' not only in the laſt examples, but in many others, the affuſion of water, by diluting the ſalts and weakening the menſtruum, makes the metal, or other diſſolved body fall to the bottom; yet if the ſaline particles of the ſolvent, and thoſe of the body be fitted for ſo ſtrict an union, that the corpuſcles reſulting from their coalitions, will not ſo eaſily be ſeparated by the particles of water, as ſuffer themſelves to be carried up and down with them; they will not be precipitated out of the weakened ſolution, but ſtill continue a part of it; as I have tried with ſome ſolution of ſilver and gold, made in acid menſtruums; but much more ſatisfactorily in ſolutions of copper, made in the urinous ſpirit of ſal-armoniac. For tho' that blue ſolution were diluted with many thouſand times the weight of the diſſolved metal; yet its ſwimming corpuſcles appear'd, by their colour, to be manifeſtly diſperſed thro' the whole liquor.

Another way whereby precipitations of bodies may be produced, by weakening the menſtruum, is to leſſen the proportion of the ſolvent to the diſſolved ſubſtance, without evaporation. Now, conſidering, that water will not diſſolve ſalts indefinitely, but when it has received its due proportion, diſſolve no more, and if they be put into it, let them fall to the bottom, and continue undiſſolved; and that if, when water is thus ſatiated, any of the liquor be evaporated, or otherwiſe waſted, it will, in proportion, let fall the ſalt it had already taken up; I concluded, that if I could add to water, any liquor, with which its particles would more readily aſſociate than with thoſe of ſalt, the depriving the ſolution of ſo many of its aqueous particles, would be equivalent to the evaporation of about as much water, as they, by being united, could compoſe. Wherefore, making a lixivium of diſtilled water, or clean rain-water, and of ſalt of tartar, ſo ſtrong, that, if a grain more were added, it would lie undiſſolved at the bottom; I put a quantity of this lixivium into a ſlender cylindrical veſſel, till it had therein reached to a proper height; then taking a ſufficient quantity of moſt pure ſpirit of wine, I poured it upon the ſaline ſolution, and ſhaking the liquors well to-

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PHYSICS. gether, to bring them to mix, I laid the tube in a quiet place; and afterwards found, that there was a conſiderable quantity of white ſalt of tartar fallen to the bottom of the veſſel; which ſalt had been merely forſaken by the aqueous particles, that ſuſtained it before, to paſs into the ſpirit of wine, wherewith they were more diſpoſed to aſſociate. This I concluded, becauſe having, before I poured on the ſpirit, made a mark on the glaſs, to ſhew how far the lixivium reached, I found, that after the precipitation, the lixivium, which remained yet ſtrong enough to continue unmixed with the incumbent ſpirit, was ſunk with its ſurface, conſiderably below the mark; the ſpirit of wine having gained in extent, what it loſt in ſtrength by receiving ſo many aqueous particles into it. I alſo made the like trial with dephlegmed ſpirit of wine, and as ſtrong a brine, as I could procure from common ſalt diſſolved without heat, in water; whereby I obtained a conſiderable proportion of finely-figured ſalt, which was let fall to the bottom. But this experiment, to be ſucceſsful, requires greater care than the former. To confirm, and vary this way of precipitation, I made a clear ſolution of gum arabic in common water, and poured upon it a little high rectified ſpirit of wine, whereby there was made a large precipitation of a light, and purely white ſubſtance. And for farther confirmation, I diſſolved a full proportion of *myrrh* in fair water, and into the filtred ſolution, which was tranſparent, but of an high-brown colour, dropped a large proportion of dephlegmed ſpirit of wine, which made a great precipitation of the gum. Theſe inſtances ſeem to ſhew, that ſimple water is a real menſtruum, which may have its diſſolving, and ſuſtaining virtue, weakened by the addition of liquors, much ſtronger than it*.

By inſiſting upon theſe ſeveral ways, whereby precipitations may be mechanically performed and accounted for, I would not be thought to deny, that there are any omitted. Theſe were only the chief which

* Sir *Iſaac Newton* ſpeaks thus of precipitation. "When oil of tartar *per deliquium*," ſays he, "being poured into the "ſolution of any metal, precipitates the "metal, and makes it fall down to the "bottom of the liquor in form of mud; "does not this argue, that the acid par"ticles are attracted more ſtrongly by "the ſalt of tartar, than by the metal; "and by the ſtronger attraction go from "the metal to the ſalt of tartar? And "ſo when a ſolution of iron in *Aqua "fortis*, diſſolves the *Lapis Calaminaris*, "and lets go the iron; or a ſolution of "copper diſſolves iron immerſed in it, and "lets go the copper; or a ſolution of "ſilver diſſolves copper, and lets go the "ſilver; or a ſolution of mercury in "*Aqua fortis* being poured upon iron, "copper, tin, or lead, diſſolves the me"tal, and lets go the mercury; does not "this argue, that the acid particles of "the *Aqua fortis* are attracted more "ſtrongly by the *Lapis Calaminaris*, than "by iron, and more ſtrongly by iron "than by copper, and more ſtrongly by "copper than by ſilver, and more ſtrong"ly by iron, copper, tin, and lead, than "by mercury?" *Newton. Optic.* p. 355, 356.

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at preſent occur'd. And I ſhou'd be glad to have the ſubject conſider'd as it deſerves; for the doctrine and hiſtory of precipitations, well delivered, will be a thing of more extent and moment, than ſeems hitherto to have been imagined; ſince, not only ſeveral of the morbific changes in the blood, and other fluids of the human body, may thereby be the better underſtood, and prevented; but, alſo, in the practical part of mineralogy, many uſeful things may, probably, be performed by means of ſuch a doctrine and hiſtory. PHYSICS.

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THE MECHANICAL ORIGIN OF Corroſiveneſs and Corroſibility.

SECT. I.

The theory of corroſiveneſs.

I Do not here deſign to treat of corroſiveneſs, in their ſtrict ſenſe of the word, who aſcribe this quality only to liquors, which are conſiderably acid, or ſour, as *Aqua fortis*, ſpirit of ſalt, vinegar, juice of lemmons, *&c.* but in a greater latitude, ſo as to make it almoſt equivalent to the diſſolving power of liquors; and in this ſenſe, the properties which ſeem moſt proper to render a liquor corroſive, are all of them mechanical.

And firſt, 'tis requiſite, that a corroſive menſtruum, ſhou'd abound with corpuſcles not too big to get in at the pores of the body to be diſſolved, nor yet ſo minute, as to paſs thro' them; as the rays of light thro' glaſs; or be unable, by reaſon of their great ſlenderneſs and flexibility, to disjoin the parts they invade. Secondly, that theſe corpuſcles be of a ſhape fit to inſinuate themſelves into the pores above-mentioned, in order to diſſociate the ſolid parts. Thirdly, that they have a competent degree of ſolidity to disjoin the particles of the body to be diſſolved; which ſolidity of ſolvent particles is ſomewhat diſtinct from their bulk, as may appear by comparing a ſtalk of wheat, and a metalline wire of the ſame diameter. Fourthly, that the corpuſcles of the menſtruum, be ſuch as are fit to ſeparate the parts of the invaded body, either by their ſhape, minuteneſs, or fitneſs to have their action befriended by aſſiſting cauſes; ſuch as, firſt, the preſſure of the atmoſphere, which may impel them into the pores of bodies, not filled with a ſubſtance ſo reſiſting as common air:

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air: as we ſee, that water will, by the prevalent preſſure of the ſurrounding air or water, be raiſed to the height of ſome inches in capillary glaſs tubes; and in the pores of ſponges, whoſe conſiſtent parts yielding eaſier than the ſides of glaſs-pipes, thoſe pores will be enlarged, and conſequently the ſides disjoined, as appears by the dilatation, and ſwelling of the ſponge: and ſecondly, the agitation, that the intruding corpuſcles may be fitted to receive in thoſe pores, by the tranſcurſion of ſome ſubtile ethereal matter; or by the numerous pulſes of the ſwimming corpuſcles of the menſtruum it ſelf; whereby, like ſo many little wedges, and levers, they may be enabled to force aſunder the little parts, between which they inſinuate. But to come to experiments.

1. It is obvious, that tho' the juice of grapes is ſweet, whilſt it retains the texture which belongs to it when new; yet after fermentation, it degenerates into vinegar: in which liquor, to a multitude of the more ſolid corpuſcles of the muſt, their frequent and mutual attritions may be ſuppoſed to have given edges; and thus, perhaps, the confuſed agitation unſheathed ſome acid particles, which at firſt lay concealed in the muſt. Now, this liquor, that by the fore-mentioned mechanical changes is become vinegar, abounds with corpuſcles, which, on account of their edges, and penetrative ſhape, will diſſolve coral, crabs-eyes, ſome ſtones, *Lapis ſtellaris* in particular, as alſo minium, and even crude copper. And not only the diſtilled ſpirit of it will do theſe things more powerfully; but the ſaline particles, that uſually remain after diſtillation, may, by being diſtilled, and cohobated *per ſe*, or by being ſkilfully united with the ſpirit, be brought to a menſtruum, of no ſmall efficacy in the diſſolution of metalline bodies, too compact for the mere ſpirit it ſelf to work upon. Vinegar may, alſo, be made of ſeveral other ſweet things, and even of honey ſkilfully fermented with a ſmall proportion of common water. *Confirm'd by experiments.*

2. Moreover, ſeveral dry woods, and other bodies, which paſs for inſipid, afford, by diſtillation, acid ſpirits, that will diſſolve coral, pearls, *&c.* and alſo, corrode ſome metals. So that the violent operation of the fire which deſtroys what is call'd the form of the diſtill'd body, and works as a mechanical agent, produces an acid, corroſive menſtruum.

3. 'Tis obſerved by refiners, that *Aqua fortis*, and *Aqua regis*, diſſolve metals, much more ſpeedily, when an external heat gives their inteſtine motions a new degree of velocity, which is but a mechanical thing; yet this additional agitation is that, without which ſome menſtruums will not ſenſibly operate on bodies at all; as we have tryed by keeping quick-ſilver in three or four times its weight of oil of vitriol, whereby the mercury was not diſſolved or corroded, tho' kept for a long time; but when the oil of vitriol was excited by a convenient heat, it corroded the mercury into a fine white calx, which by the affuſion

PHYSICS. affuſion of fair water, would be preſently turned into a precipitate, of the colour and nature of a turbith. And having diſſolved, in a weak ſpirit of ſalt, a fourth part of its weight of fine cryſtals of nitre, we found, that it would not, in the cold, diſſolve leaf-gold; but when the menſtruum was a little heated by the fire, that ſolution was readily made. In ſome caſes alſo, tho' the external heat be ſmall, yet there may happen another briſk one, and greatly aſſiſt in the diſſolution of a body; as for inſtance, of quick-ſilver in *Aqua fortis*. For it is not ſtrange to find, that when a full proportion of that fluid metal has been taken, the ſolution, tho' at firſt altogether liquid, and as to ſenſe uniform, comes to have, after a while, a large quantity of coagulated matter at the bottom; of which the cauſe may be, that in the very act of corroſion, there is excited an intenſe degree of heat, which giving a new degree of agitation to the menſtruum, makes it diſſolve much more, than afterwards, when the conflict is over, it is able to keep up.

4. We have obſerved alſo, that agitation, in ſome caſes, ſo much promotes the ſolutive power of ſaline bodies, that tho' they be not reduc'd to that ſubtilty of parts, to which a ſtrong diſtillation brings them; yet they may, in their groſſer form, have the power to work on metals. By barely boiling ſome ſolutions, of ſalts of a convenient ſtructure, as nitre, ſal-armoniac, *&c.* which leaf-gold, ſilver, *&c.* we have corroded theſe metals, and can diſſolve ſome others. And, by boiling crude copper filings with ſublimate, and common water, we were able, in no long time, to make a ſolution of the metal.

5. Sometimes, likewiſe, ſo languid an agitation, as that which ſeems but ſufficient to keep a liquor in the ſtate of fluidity, may ſuffice to give a dry body a corroding power, which it could not otherwiſe exerciſe; as in the way of writing upon the blade of a knife with corroſive ſublimate, wetted with common water. For after a while, all the parts of the blade, that ſhould not be fretted, being protected by a covering of wax, the ſublimate will corrode, only where way has been made for it in the wax by a bodkin; and the letters will be the more or leſs deeply etch'd, according to the time the ſublimate is ſuffered to lie on: and if we only intend a legible impreſſion, a few minutes may ſerve the turn.

6. Beſides, ſeveral bodies, found unable to diſſolve others, in moderate degrees of heat, may yet, by intenſe degrees, be made fit ſolvents for them. Having a diſtilled liquor, which was rather ſweet to the taſte, than acid; I in vain try'd to make it work on pearls, in a more than ordinary warm digeſtion; yet the glaſs being for many hours kept in ſuch an heat of ſand, as made the liquor boil, we had a thorough diſſolution. And tho' the ſolvents of crude gold, are generally diſtilled acid liquors; yet alcalizate bodies without the help of any liquor, will be enabled, by a melting fire, in no long time, to penetrate, and tear aſunder the parts, even of crude gold;

ſo

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so that it may afterwards be easily taken up in liquors, which are not acid, or even by water itself. PHYSICS.

7. And tho' pure salt-petre, when dissolved in water, is not observed to be a fit menstruum to dissolve some metals, or so much as coral itself; yet when by a convenient distillation, its parts are split, and by attrition, or other mechanical ways, reduced to the shapes of acid, and alkalizate salts; it then affords two sorts of menstruums of very differing natures; which, between them, dissolve a great number and variety of bodies; as the spirit of nitre, without addition, is a solvent for most metals, *viz.* silver, mercury, copper, lead, *&c.* and also several mineral bodies, as tin-glass, spelter, *Lapis Calaminaris*, &c. and the fixed salt of nitre operates upon sulphureous minerals, such as common sulphur, antimony, *&c.*

8. By the preceding trials, it has appeared, that the increase of motion in the more penetrating corpuscles of a liquor, contributes much to its solutive power; I shall now add, that the shape, and size, which are mechanical properties, and sometimes also the solidity of the same corpuscles, eminently concur, to qualify a liquor for dissolving a particular body. And of this, some of the more familiar practices of chymists may supply us with instances. For there is no account so probable, as may be given upon this supposition, why *Aqua fortis*, which will dissolve silver, without meddling with gold, should, by the addition of a fourth part of its weight of sal-armoniac, be turned into *Aqua regis*, which, without touching silver, will dissolve gold. But there is no necessity to have recourse to so gross and compounded a body, as sal-armoniac, to enable *Aqua fortis* to dissolve gold: for the spirit of common salt alone, being mixed in a due proportion, will suffice for that purpose. Which, by the way, shews, that the volatile salt of urine and soot, which concur to make sal-armoniac, are not necessary to the dissolution of gold; for which a solvent may also be made with *Aqua fortis* and crude sea-salt. Nay, the mechanical affections of a menstruum may have such an interest in its solutive power, that even mineral, or metalline corpuscles, may become useful ingredients of it, tho' perhaps it be a distilled liquor; as might be illustrated by the operations of some compounded solvents, such as is the oil of antimony, made by repeated rectifications of what chymists call its butter, which greatly abounds in an antimonial substance.

9. But to shew, that a smaller change than one would imagine, of the bulk, shape, or solidity of the corpuscles of a menstruum, may fit it to dissolve a body, it would not work on before; we find not, that our spirit of salt here in *England*, will at all dissolve crude gold; but by putting some leaf-gold into a convenient quantity of good spirit of salt, when we had drop'd in spirit of nitre, till the mixture was just able, in a moderate heat, to dissolve the gold, we found, that we had been obliged to employ only twelve drops of

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PHYSICS. the latter liquor, to an ounce of the former; ſo that ſuppoſing each of theſe drops to weigh a grain, the fortieth part of ſpirit of nitre being added, ſerved to turn the ſpirit of ſalt into a kind of *Aqua regis*. But to know the proportion more exactly, we weighed ſix other drops of the ſame ſpirit of ſalt, and found them not fully to amount to three grains and an half: whence it appeared that we added but about a ſeventieth part of the nitrous ſpirit, to that of ſalt.

10. The experiments hitherto recited, relate chiefly to the production of corroſive menſtruums; I ſhall now give an account of two experiments, which I made, manifeſtly to leſſen, or quite deſtroy corroſiveneſs in liquors, very conſpicuous for that quality. One of the corroſive menſtruums yet known, is oil of vitriol, which will fret ſeveral metals, minerals, and a great number and variety of animal and vegetable bodies to pieces; yet if, for a while, you digeſt with it, an equal weight of *highly* rectified ſpirit of wine, and afterwards diſtil the mixtures very warily, you may obtain much of a liquor not corroſive at all; and the remaining ſubſtance will be reduced partly into a liquor, which, tho' acid, is not more ſo, than one part of good oil of vitriol will render ten times as much common water, by being well mixed with it; and partly into a dry ſubſtance, which hath ſcarce any taſte at all, much leſs a corroſive one.

11. And tho' *Aqua fortis* be the moſt generally employ'd of corroſive menſtruums; yet to ſhew how much the power of corroding may be taken away by changing the mechanical texture of a menſtruum, without ſeeming to deſtroy the fretting ſalts; I took equal parts of good *Aqua fortis*, and highly dephlegmed ſpirit of wine; and having mixed them warily, by degrees, we united them, by two or three diſtillations of the whole mixture; which we afterwards found not to have the leaſt fretting taſte, and to be ſo deprived of its corroſive nature, that it would not work upon ſilver, tho' by precipitation, or otherwiſe, reduced to very ſmall parts; nay, it would ſcarce ſenſibly work, in a long time, on filings of copper, or upon other bodies, which mere vinegar, or pehaps rheniſh wine will corrode. And with another ſpirit, not urinous, and afterwards with ſpirit of wine, we ſhewed a more ſurprizing inſtance of the power of deſtroying the corroſiveneſs of a menſtruum. For having put a piece of copper-plate into one ounce of *Aqua fortis*; when the liquor was eagerly working upon the metal, I cauſed an ounce of the pure ſpirit of wine, to be poured upon the agitated mixture; whoſe effervescence, at the firſt inſtant, ſeemed to be much increaſed; but it was preſently after checked, and the menſtruum being ſpeedily diſarmed of its corroſiveneſs, the remaining copper was left undiſſolved at the bottom. Nor are theſe the only acid menſtruums, which I have, in this way, corrected: I applied it alſo to others, as ſpirit of nitre, and even *Aqua regis* itſelf; but it has not an equal operation upon all, and the leaſt upon ſpirit of ſalt;

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ſalt; as on the other ſide, it ſucceeds to greater ſatisfaction upon ſtrong ſpirit of nitre. PHYSICS.

Moſt of the chymiſts pretend, that the ſolution of bodies are performed by a certain cognation and ſympathy between the menſtruum, and the body whereon it is to operate: and indeed, in ſeveral inſtances, there is, as it were, a relation between the menſtruum and the body to be diſſolved; as when ſulphur is diſſolved by oils, whether expreſs'd or diſtilled: yet, as the opinion is generally propoſed, I cannot acquieſce in it; becauſe there are various ſolutions and other phenomena, where it will not take place; and becauſe, even in thoſe inſtances wherein it is thought moſt applicable, the effect ſeems to depend upon mechanical principles.

12. And firſt, it will be difficult to ſhew, what relation there is between ſal-gem, antimony, iron, zink, bread, camphire, *Lapis Calaminaris*, fleſh of ſeveral kinds, oyſter-ſhells, chalk and quick-lime; ſome of which belong to the vegetable, ſome to the mineral, and ſome to the animal kingdom; yet all of theſe, and ſeveral others may, even without the aſſiſtance of external heat, be diſſolved or corroded by one ſingle mineral menſtruum, oil of vitriol.

13. I obſerve alſo, that a diſſolution may be made of the ſame body, by menſtruums, to which the chymiſts attribute mutual antipathy, and which, therefore, are not likely to ſympathize with the ſame third body: thus I found, that by *Aqua fortis*, and ſpirit of wine, upon whoſe mixture, there enſues a conflict, with great efferveſcence, will each of them a-part, readily diſſolve crude zink, as alſo the filings of copper. Pure ſpirit of wine, and oil of vitriol, as great a difference as there is between them in many reſpects, will each of them diſſolve camphire: and to theſe might be added other inſtances of the like nature.

14. As to what is commonly ſaid, that oils diſſolve ſulphur, and ſaline menſtrua metals, by reaſon of their ſimilitude; I anſwer, that where there is any ſuch ſimilitude, it may very probably be aſcribed not ſo much to the eſſential forms of the bodies, that are to work on each other, or to their ſalt, ſulphur, or mercury; but to the congruity between the pores and figures of the menſtruum, and the body diſſolved by it; and to ſome other mechanical properties of them. Thus ſilver will not only be diſſolved by nitre, which is reckon'd a ſalt, but will amalgamate with quick-ſilver, and alſo, by the operation of brimſtone, be eaſily incorporated with that mineral, which chymiſts account of ſo oleaginous a nature, and inſoluble in *Aqua fortis*.

15. And as for thoſe diſſolutions, which are made with oily and inflammable menſtruums, of common ſulphur, and the other like bodies; they do not plead for them ſo clearly, as chymiſts imagine. For if ſuch menſtruums operate, upon account of their ſulphureous nature; whence is it, that highly rectified ſpirit of wine will not diſſolve even the

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PHYSICS. flowers of brimſtone, which eſſential, as well as expreſs'd oils, eaſily take up? And this ſpirit of wine, itſelf, will immediately do, if by the help of an alkali, the texture of the brimſtone be altered; tho' the only thing added to the ſulphur, being an incombuſtible ſubſtance, is nothing near of ſo ſulphureous a nature as the flowers, and need have no relation, upon account of its origin with ſpirit of wine, as ſalt of tartar has; ſince I have tried, that fixed nitre will do the ſame.

16. Salt-petre, being looked upon by chymiſts, as a very inflammable body, ought, according to them, to be of a very ſulphureous nature; yet we find, that it is not readily diſſolved in chymical oils, but in water. Chymiſts tell us, that the ſolutions of alkalies, ſuch as ſalt of tartar, or of pót-aſhes, in common oils, proceed from the great ſimilitude between them; but I demand, whence it happens, that ſalt of tartar will, by boiling, be diſſolved in the expreſs'd oil of almonds, or of olives, and be reduced with it to a ſoapy body; tho' with the eſſential oil of juniper, or aniſeed, *&c.* where what they call the ſulphur, is made pure and penetrant, you may boil ſalt of tartar twenty times as long without making any ſoap of them, or perhaps any ſenſible ſolution of the alkali? And chymiſts know, how unſucceſsfully it is attempted to diſſolve pure ſalt of tartar, in pure ſpirit of wine. I will not urge, that tho' the moſt conſpicuous mark of ſulphur be inflammability, and is, in an eminent degree, to be found in oil, as well as ſulphur; yet an alkali, and water, which are neither ſingly, nor when united, inflammable, will diſſolve common ſulphur.

17. But to make it probable, againſt the chymiſts, that the ſolution of ſulphur in expreſs'd oils, depends upon ſomething beſides the abundance of the ſecond principle in both the bodies, many chymical writers themſelves reckon *Aqua regis*, which is plainly a ſaline menſtruum, and diſſolves copper, iron, coral, *&c.* like acid liquors, among the ſolvents of ſulphur; and by that power, amongſt other things, diſtinguiſh it from *Aqua fortis*. On the other ſide, if there be a congruity, between an expreſs'd oil, and another body, tho' it be ſuch, as by its being eaſily diſſolved in acid ſalts, chymiſts ſhould pronounce of a ſaline nature, an expreſs'd oil will readily work upon it; as I have tried by digeſting copper filings, with oil of ſweet almonds, which took up, like a corroſive liquor, ſo much of the metal, as to be deeply coloured thereby. Nay, even with milk, I have found a kind of diſſolution made of crude copper, as appeared by the greeniſh blue colour the filings acquired, when they had been well drenched in it, and left for a certain time in the veſſel, where the air had very free acceſs to them.

18. Beſides the argument drawn from *Aqua regis*, it may be proper to urge another of the ſame kind againſt the generality of the followers of *Helmont* and *Paracelſus*, who allow of the operations of the alkaheſt. It is affirmed, that this irreſiſtible menſtruum will diſſolve all tangible bodies into inſipid water; but then as, on the other ſide, it

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it will be very hard to conceive, how a particular menstruum, which is determined to be either acid, lixiviate, or urinous, *&c.* should be able to dissolve so great a variety of bodies, of differing, and perhaps contrary natures; so, on the other, if the alkahest be not a particular menstruum, it greatly discredits the opinion of the chymists, who will have some bodies dissolvable only by acids, others by fixed alkalies, and others again by volatile salts; since a menstruum which is neither acid, lixiviate, nor urinous, is able to dissolve bodies, in some of which, one, and in others, another of those principles is predominant. So that if a liquor be conveniently qualified, it is not necessary it should be either acid, to dissolve pearl, or coral, or alkalizate, to dissolve sulphur.

19. If we duly reflect upon the usual process in making *Mercurius dulcis*, we shall find it very favourable to our hypothesis. For tho' we have already shewn, that common sublimate, made of mercury, is a highly corrosive body; yet if it be well ground, with near an equal weight of quick-silver, and be a few times sublimed, it will become so mild, as not to taste sharp upon the tongue; whence the chymists call it *Mercurius dulcis*; yet this dulcification seems to be perform'd in a mechanical way. For most parts of the salts, which made the sublimate so corrosive, abide in the *Mercurius dulcis*; but being compounded with more quick-silver, they are diluted by it, and acquire a new texture, which renders them unfit to operate, as they did before, when the fretting salts were not joined with a sufficient quantity of the mercury, to restrain their corrosive activity. And this it may do either by sheathing, or rubbing and grinding off their sharp points, or cutting edges; as by some such mechanical change, fretting salts either quite lose their sharpness, as alkalies, whilst they are imbodied with sand in common glass; or greatly abate in their corrosive acidity, as oil of vitriol, when, with steel, it composes *Vitriolum Martis*: or are else transmuted or disguised, by conjunction with some corroded bodies of a peculiar texture, as when *Aqua fortis* makes, with silver, an extremely bitter salt of vitriol; and with lead, one which is positively sweet, almost like common *Saccharum Saturni*.

20. And to shew how much the efficacy of a menstruum may depend, even upon slight mechanical circumstances; I put upon lead a large quantity of well rectified *Aqua fortis* in which the metal continued undissolved; tho', if the chymists say true, that the dissolving power of the menstruum consists only in the acid salts, with which it abounds, it seems naturally to follow, that the more of them are contain'd in a determinate quantity of the liquor, the more able it shou'd be to dissolve metalline bodies. And in effect we see, that if corrosive menstruums be not sufficiently dephlegmed, they will not work on several of them. Conjecturing, however, that the saline particles, which swam in our *Aqua fortis*, might be more thronged together, than was convenient for a body of such a texture of saline parts; I diluted the men-

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menstruum with fair water, upon which the desired fitness betwixt the agent and the patient ensued; when the liquor quickly began to fall upon the metal, and dissolved it. And thus silver, which, I found, would not dissolve in very strong *Aqua fortis*, was readily fallen upon by that menstruum, when I had weakened it with common water.

SECT. II.

The theory of corrosibility.

CORrosibility being the correspondent quality to corrrosiveness, the distinction already made of the former, will shew in what sense I use the latter. And this corrosibility, of bodies, as well as their corrosiveness, is a relative thing; since gold, for instance, will not be dissolved by *Aqua fortis*, but will by *Aqua regis*; whilst silver cannot be dissolved by the latter of these menstruums, but may by the former. And this relative property seems to consist chiefly in three requisites, all which depend upon mechanical principles.

The first is, that the body to be corroded have pores of such a magnitude and figure, that the corpuscles of the solvent may enter them, and agitate the solid parts, which inclose them: for want of this condition, glass is penetrated in a multitude of places, but not dissipated, by the incident rays of light, which permeate its pores without any considerable resistance. And tho' the interstices of a body were less minute, and capable of letting in some grosser corpuscles; yet if these, for want of solidity or rigidness, were too flexible, or of a figure unsuitable to that of the pores they should enter, a dissolution would not ensue; as it happens, when pure spirit of wine is, in the cold, put upon salt of tartar, or *Aqua fortis* upon powder of sulphur.

The second qualification is, that its consistent corpuscles be of such a bulk and solidity, as does not render them incapable of being disjoined by the action of the insinuating corpuscles of the menstruum. Agreeable to this, and the former observation, is the practice of chymists, who, when they would have a body wrought upon by a menstruum, otherwise too weak for it in its crude state, dispose it to receive the action of the solvent by previously opening it, that is, by enlarging the pores, making a communication of the corpuscles, or weakening their cohesion. Thus, several bodies are brought, by fit preparations, to be resoluble in liquors, which would not work on them before. Thus, lime-stone by calcination becomes, in part, dissoluble in water; and some metalline calces will be wrought upon by solvents, that would not touch the crude metal. Thus, tho' crude tartar is very slowly dissoluble in cold water, yet when burnt, it may be presently dissolved in that liquor. And thus, tho' the filings of silver will

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will not be at all dissolved by common water, or spirit of wine, yet if, by the interposition of the saline particles of *Aqua fortis*, the corpuscles be so disjoined, and suffer such a comminution, as they do in crystals of silver; the metal thus prepared, will easily dissolve, not only in water, but in well rectified spirit of wine. And the like solubility I have found in the crystals of lead made with spirit of verdigrease, or good distilled vinegar, and in those of copper made with *Aqua fortis*. PHYSICS.

The last disposition to corrosibility consists in such a cohesion of the parts, as is not too strong to be superable by the action of the menstruum. This condition, tho' of kin to the former, is somewhat different from it; since a body may consist of parts, either bulky, or solid, which yet may touch one another in such small portions of their surfaces, as to be much more easily dissociable, than the minute or less solid parts of another body, whose contact is more full and close, and consequently their cohesion more strict; so that the corrosibility of a body is but a mechanical relation, resulting from the mechanical properties and contexture of its parts, as they intercept pores of such sizes and figures, as fit them to those of the corpuscles of the menstruum, which enter between and disjoin them. But to confirm this doctrine with a few experiments.

1. If we put highly rectified spirit of wine upon sulphur, or its flowers, the liquor will lie quietly thereon, without making any visible solution; and if such spirit were put upon very dry salt of tartar, the salt would lie undissolved at the bottom: yet if the sulphur be first gently melted, and the salt of tartar by degrees, put to it, and mixed therewith; as there results a new texture, discoverable by the new colour, so there will arise a disposition to be dissolved, that was not before in either of the ingredients; whence, tho' the mixture be kept till quite cold, or long after, provided it be secured from the air, the spirit of wine, being put to it, will thence acquire a yellow tincture in a minute; and in less than half a quarter of an hour, a red one; being richly impregnated with sulphureous particles, discoverable by the smell, taste, and several operations. *Confirmed by experiments.*

2. Spirit of salt will not dissolve crude mercury in the cold; and I once kept them, for a considerable time, in no small heat, without finding any solution. But if mercury be precipitated *per se*, that is, reduced to a red powder without addition, by the mere operation of the fire; the texture will be so changed, that the spirit of salt will readily dissolve it.

3. And this experiment is the more remarkable; because, tho' oil of vitriol will, in a great heat, corrode quick-silver; yet I kept a precipitate *per se*, for several hours, in a considerable degree of heat, without finding it to be dissolved, or corroded by the menstruum: but, having put another parcel of the same mercurial powder into cold *Aqua fortis*, or spirit of nitre, a speedy dissolution ensued. And that this disposition to be dissolved by spirit of salt, which mercury acquires

of the operation of the fire upon it, but of ſome change of texture, produced by that operation, may be argued from hence, that, tho' ſpirit of ſalt be a very proper menſtruum to diſſolve iron, or ſteel; yet when that metal is reduced to a crocus, by the action of the fire, it leaves in the bottom of the glaſs, a conſiderable part ſcarce ſenſibly altered; ſo that the menſtruum has ſeemed rather to have extracted a tincture, than to have made an ordinary ſolution: for the colour of it was a high yellow or reddiſh; whilſt iron, diſſolved in ſpirit of ſalt, affords a green ſolution. Whether, by repeated operations with freſh menſtruums, *farther* diſſolutions might in time be made, I will not ſay; it may ſuffice for our preſent purpoſe, that iron, by the operation of the fire, acquired not, as mercury had done, a facility, but a great *indiſpoſition* to be diſſolved by ſpirit of ſalt. We varied this experiment, by employing inſtead of ſpirit of ſalt ſtrong oil of vitriol, which, being poured on a little *Crocus Martis*, made *per ſe*, did not, as that menſtruum uſually does upon filings of crude iron, readily fall upon the powder, with froth and noiſe, but reſted for ſeveral hours calmly upon it, without producing any ſenſible warmth.

4. And it agrees very well with our doctrine about the dependance of the corroſibility of bodies upon their texture, that from ſeveral of them, whilſt they are in conjunction with others, there reſult maſſes, eaſily diſſoluble in liquors, wherein a great part of the matter, if ſeparated from the reſt, would not be at all diſſolved. Thus, common vitriol is eaſily diſſolved in mere water; but if ſkilfully calcined, it will yield near half its firſt weight of inſipid colcothar, which is ſoluble, neither in water, in *Aqua fortis*, or *Aqua regis*; tho' ſometimes theſe will colour themſelves upon it. We ſee, likewiſe, that ſimple water will by boiling it with harts-horn, diſſolve and make a jelly thereof; and yet, when calcined, common water is no longer a fit ſolvent for it, nor even oil of vitriol a thorough one.

5. I ſhall recommend to the followers of *Helmont*, an experiment of his, which ſeems to ſuit with the doctrine propoſed. He tells us, that if, by a certain ſubtile menſtruum, quick-ſilver be diveſted of its external ſulphur, as he terms it, all the reſt of the fluid metal, which he ſtiles the kernel of mercury, will be no longer corroſible by it. So that upon this ſuppoſition, tho' common quick-ſilver be ſo ſuited to *Aqua fortis*, that the ſame quantity of that will diſſolve more of it, than of any other metal; yet, if by the deprivation of ſome portion of it, the latent texture of the metal be altered, tho' not the viſible appearance, the body, which before was ſo eaſily diſſolved by *Aqua fortis*, ceaſes to be at all diſſoluble by it.

6. As for thoſe chymiſts, who credit the ſtrange things affirmed of the alkaheſt; we may urge them with what is delivered by *Helmont*, where he aſſerts, that all ſolid bodies, as ſtones, minerals, and metals themſelves, by having this liquor duly abſtracted, or diſtilled off from them,

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heft to be totally abstracted, what other change, than of texture, can be reasonably imagined to have been made in the transmuted bodies? Yet several of them, as flints, rubies, sapphires, gold, silver, &c. which were insoluble before; some of them in any known menstruums, and others in any but corrosive liquors; become capable of being dissolved in common water,

7. It is a remarkable phenomenon, and confirms our opinion, about the interest of mechanical principles in the corrosive power of menstruums, and the corrosibility of bodies, that is produced in the following experiment. If we put large grains of sea-salt into common water, they will be dissoved calmly therein, without any appearance of conflict; but if such grains of salt be put into good oil of vitriol, that liquor will fall furiously upon them, and produce, for a long while, an hissing noise with fumes, and numerous bubbles, as if a potent menstruum were corroding some stubborn metal.

8. And tho' *Aqua fortis* or *Aqua regis* poured upon filings of copper, will work upon them with much noise and ebullition, I have tried that good spirit of sal-armoniac, or of urine, being put upon the like filings, and left there, without stopping the glass, will quickly begin to work on them, and quietly dissolve them, almost as water dissolves sugar. And even with oil of turpentine, I have dissolved crude copper; and the experiment seemed to favour our conjecture the more, because having made it several times, it appear'd that the common unrectified oil would perform the solution much quicker, than that which was purified by rectification; which, tho' more subtile, and penetrating, was, it seems, on that account, less fit to dissolve the metal, than the grosser oil, whose particles might be more solid, or more advantageously shaped, or on some other mechanical account better qualified for the purpose.

9. Dissolve good silver in *Aqua fortis*, and precipitate it with a sufficient quantity of spirit of salt; then having wash'd the calx, which will be very white, with common water, and dried it well, melt it, with a moderate fire, into a fusible mass, which will be very much of the nature with what the chymists call *Cornu Lunæ*, which they make by precipitating dissolved silver, with a bare solution of salt, made in common water. And tho' spirit of salt, and silver dissolv'd in *Aqua fortis*, will each of them apart, readily unite with simple water, our *Luna Cornea* will not, but is so indisposed to dissolution, that I have kept some long in digestion, with *Aqua fortis*, and some in *Aqua regis*, and in no faint degree of heat, without being able to dissolve it like a metal; the menstrua having, indeed, tinged themselves upon it, but left the composition dissolved at the bottom.

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THE MECHANICAL PRODUCTION OF TASTES, and ODOURS.

SECT. I.

The mechanical cause of tastes.

ACcording to my notion of tastes, they depend upon the magnitude, figure, and motion of the sapid corpuscles, considered, either separately, and as the properties of single and very minute particles of matter; or else in a state of conjunction, as two or more of these properties, and the particles they belong to, may be combined, or associated, either amongst themselves, or with others, which were not sapid before. And as these coalitions, and other associations, come to be diversified; so the tastes resulting from them, will be altered or destroy'd. By taste, considered as belonging to the object, I mean that quality, or whatever else it be, which enables a body by its operation to produce in us the sensation, we call taste. That this quality, or whatever else it be which makes or denominates an object sapid, may so depend upon the shape, size, motion and other mechanical affections of the small parts of the body tasted, and result from the association of two or more of them, not excluding their congruity, or incongruity to the organs of tasting, may be made probable by the following instances.

A body, almost insipid, divided into two bodies of very strong and very differing tastes.

1. It is observed, that salt-petre refined, and freed from the sea-salt that is mixed with it, rather cools the tongue, than makes any sapid impression on it, bating a very faint and languid bitterness, which seems to be its proper taste; yet being distill'd, by the way of inflammation, or by the help of a tasteless addition, it affords both a spirit, which is extremely sharp upon the tongue, and will dissolve several metals, and

various metals, and other concretes out of thoſe ſolutions, which have been made of them by the ſpirit.

2. If upon the liquor of fixed nitre, made *per deliquium*, you warily drop juſt enough good ſpirit of nitre, to ſatiate the alkali, you may, by a gentle evaporation, and ſometimes without it, obtain cryſtals, which will have, upon the tongue, neither a ſharp, nor an alkalizate taſte, but the faint and ſcarce ſenſible bitterneſs, that belongs to pure ſalt-petre. The like production of ſalt-petre we have ſometimes had in far leſs time, and ſometimes indeed in a trice, by ſubſtituting, inſtead of the fixed ſalt of nitre, the ſaline parts of good pot-aſhes, carefully freed, by ſolution and filtration, from the earthy and feculent ones. *Two bodies, the one highly acid, and the other alkalizate, produce a third almoſt inſipid.*

Now the phenomena of theſe two experiments may ſeem explicable from the new magnitudes, and figures of the particles, which the fire, by breaking, or forcibly rubbing them one againſt the other, or alſo againſt the corpuſcles of the addition, may be preſumed to give them; as if, for example, allowing the corpuſcles of nitre to be little priſms, whoſe angles and ends are too obtuſe to make deep impreſſions on the tongue; if theſe little priſms be, by a violent heat, ſplit, or otherwiſe broken, or forcibly made to grind one another, they may come to have parts ſo much ſmaller than before, and endowed with ſuch ſharp ſides and angles, that being diſſolved and agitated by the ſaliva, which uſually moiſtens the tongue; their ſmallneſs may give them free acceſs to the pores of that organ; and the ſharpneſs of their ſides and points may fit them variouſly to ſtab and cut the nervous *Papillæ* of it, according to the grand diverſities, as to ſhape and bulk, of the ſapid particles. And this being granted, it ſeems farther conceivable, that, when the alkalizate and acid particles were put together in the fluid mixture, wherein they ſwam, many of them might, after a multitude of various joſtlings, and occurſions, meet with one another ſo luckily, as to re-compoſe little priſms, or convene into other bodies, almoſt like thoſe, that made up the cryſtals of nitre, before it was expoſed to the fire. Thus, tho' a priſm of iron may have ſuch a ſhape, as to be wholly unfit to pierce the ſkin; yet 'tis poſſible to cut it by tranſverſe planes, reaching to the oppoſite baſes or ends, ſo as to make wedges, which, by the ſharpneſs of their angles, may be fit to cleave wood, and cut the ſkin; and theſe wedges, being again put together, after a requiſite manner, may recompoſe a priſm, whoſe extremes ſhall be too blunt to ſerve the former purpoſe.

3. We very warily pour'd upon cryſtals of ſilver, diſſolved in good *Aqua fortis*, or ſpirit of nitre, ſtrong brine, made of common ſalt and water. The mixture of theſe being dried, and afterwards fuſed in a crucible, and kept a competent time in that ſtate, affords a tough *An inſipid mixture of bitter and ſalt bodies.*

PHYSICS. maſs, called by the chymiſts *Luna cornea*, which being lick'd ſeveral times, will ſcarce be judged other than inſipid; nor will it be eaſily brought to diſſolve in much more piercing menſtruums than our ſaliva.

An inſipid mixture of ſweet and ſalt bodies.

4. Take a ſtrong ſolution of minium, made with good ſpirit of vinegar; or take *Saccharum Saturni*, diſſolved in a convenient vehicle; and be very careful to put to it, by degrees, a juſt proportion of ſtrong ſpirit of ſal-armoniac, or the like urinous ſpirit, till the whole be precipitated; and if the two former taſtes are not ſufficiently deſtroy'd thereby, the mixture, being dried and fluxed, as in the *Luna cornea*, will become inſipid.

An inſipid body and a ſour one, make another more bitter than gall, or aloes.

5. Diſſolve in ſtrong ſpirit of nitre, or good *Aqua fortis*, as much pure ſilver, as the menſtruum will take up; this ſolution being filtred, has been often eſteemed more bitter than gall, wormwood, aloes, *&c.* and if the ſuperfluous moiſture be abſtracted, you may, by coagulation, obtain cryſtals of ſilver, that have been judged more ſtrongly bitter than the ſolution. And that the corpuſcles of theſe cryſtals ſhould leave a far more laſting taſte of themſelves than the moſt bitter bodies, will not ſeem ſtrange, if we take notice how deep the particles of theſe cryſtals may pierce into the ſpongy organs of taſte; ſince, if one does but touch the pulp, or nail of one's finger, firſt a little wetted, with the powder of ſuch cryſtals, it will penetrate, and ſtick ſo faſt there, that you cannot in a reaſonable time get off the ſtain.

An inſipid body and a corroſive one made into a ſweet ſubſtance.

6. Put purified *Aqua fortis*, or ſpirit of nitre, upon good minium, letting them work on one another in a gentle heat, till the liquor has diſſolved its full proportion of the metal; when, if the ingredients be good, and the operation rightly performed, the menſtruum will have a ſweetneſs, like that of ordinary *Saccharum Saturni*. But if the minium be adulterated, as often it is; or the ſpirit of nitre, or *Aqua fortis* be mixed with ſpirit of common ſalt, or other unfit ingredients, the experiment will not ſucceed, as I have more than once obſerved.

Liquors corroſive enough to diſſolve metals, obtain'd from the ſweeteſt bodies.

7. If ſugar be put into a large retort, and warily diſtilled, it will afford, among other things, a large quantity of red ſpirit, which being ſlowly rectified, loſes its colour, and comes over clear. The *Caput mortuum* of the ſugar may be found either almoſt, or wholly inſipid. And tho' the ſpirit will be of a very piercing taſte, yet it will be very far from any kind of ſweetneſs; and tho' that liquor be thought homogeneous, and to be one of the principles of the analyzed ſugar, yet I found it to be a mixture of two ſpirits; with the one of which, beſides bodies of a leſs cloſe texture, I diſſolv'd crude copper; as was eaſy to be ſeen by the deep and lovely colour of the ſolution. And to theſe four ſpirits, afforded by ſugar itſelf, we have reſtored a kind of ſaccharine ſweetneſs, by compounding them with the particles of ſo inſipid a body as minium; part of which they will in digeſtion diſ-

ſolve.

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8. Put ſome fine cryſtals of ſilver into a good retort, and then diſtilling them in a ſand-furnace, capable of giving them ſo ſtrong a fire, as to drive away all the ſpirits from the ſilver, this, remaining behind, will, according to its metalline nature, be inſipid, and the ſpirits, that are driven away from it, will unite in the receiver into an acid and corroſive menſtruum.

A body, bitter in the higheſt degree, divided into two ſubſtances, the one extremely ſour, and the other perfectly inſipid.

9. As the following operation may help to diſcover the figures of the particles of diſſolved metals, and other bodies; ſo it is very fit to ſhew how much taſte may be diverſified by, and conſequently depend upon texture; ſince a body, that hath no taſte, may, in conjunction with ſapid bodies, give them ſtrong taſtes, all differing from one another, and each of them from that, which the ſapid bodies had before. Zink will be diſſolved not only by *Aqua fortis*, *Aqua regis*, oil of vitriol, ſpirit of nitre, ſpirit of ſalt, and other mineral menſtruums, but alſo by vegetable ſpirits, as diſtilled vinegar; and by animal ones too, as ſpirit of ſal-armoniac; tho' the one be acid, and the other urinous. And if the ſeveral ſolutions, which may be made of this mineral, by ſo many different liquors, be compared, the number of their different taſtes will ſuffice to ſhew that a variety of taſtes is producible from one inſipid body, by aſſociating it with different menſtrua.

Variety of taſtes produced in one inſipid body, by aſſociating it with different menſtruums.

10. The next experiment may paſs for a converſe of the foregoing; and as it ſerves as well as that to diſcover the ſtructure of the minute parts of metalline and mineral bodies; ſo it may, better than that, ſerve to illuſtrate the doctrine of taſtes; by ſhewing, that a ſingle, ſimple body, endowed with a peculiar taſte, may, by being compounded with others, each of them inſipid of itſelf, produce a conſiderable number of differing taſtes. More inſtruments than one might be uſed in this experiment; but of thoſe which are known, and eaſily obtain'd, the moſt proper are ſpirit of nitre, and good *Aqua fortis*; which, with refined ſilver, make a ſolution bitter as gall; with lead, one of a ſaccharine ſweetneſs; with that part of tin, they will keep diſſolved, a taſte very different from both the former, but not odious; with copper an abominable taſte; and with mercury and iron, other kinds of bad taſtes. Nor are metals the only mineral bodies they thus work upon: they alſo diſſolve tin-glaſs, antimony, braſs, emery, zink, *&c.* all which together make up no deſpicable number of different taſtes.

Variety of taſtes produced with one menſtruum, by aſſociating it with inſipid bodies.

11. The next inſtance is ſtill more proper for our purpoſe; becauſe the corroſive menſtruum is here neither mortified by fixed nor urinous ſalts, ſuppoſed to be of a contrary nature to it; nor yet diſarmed by corroding of metals, or other ſolid bodies. The experiment being ſomewhat dangerous when made in great quantities, it may anſwer our end,

Two liquors, one highly corroſive, and the other very pungent, compoſe a body of a pleaſant aromatic taſte.

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PHYSICS. end, to make in leſs, as follows. Take one ounce of ſtrong ſpirit of nitre, or of very good *Aqua fortis*, and very gradually put to it another ounce of rectified ſpirit of wine. When theſe two liquors are well mixed, and grown cold again, diſtil them totally over together, to unite them exquiſitely into one liquor; in which, if the operation hath been well perform'd, the corroſive particles of the ſalts will not only loſe all their cutting acidity; but by their new compoſition with the vinous ſpirit, the liquor acquires a vinous taſte, which is very pleaſing and aromatic.

The peculiar taſtes of natural bodies, imitated by art.

12. Perhaps it will not be erroneous to conceive, that whatever be the agent in reference to thoſe taſtes, which are ſaid to be ſpecific to this or that plant; yet that, on whoſe immediate account it is, or becomes of this or that nature, is a complication of mechanical properties, ſuch as ſhape, ſize, *&c.* in the particles of the matter, which is ſaid to be endowed with ſuch a ſpecific taſte.

To illuſtrate this, I attempted to imitate the taſte of ſome natural bodies by artificial ones; but found it not eaſy, before-hand to know the ſucceſs of ſuch trials. Making ſome experiments to alter the ſenſible qualities of oil of vitriol, and ſpirit of wine, I obtained from them, among other things, a certain liquor, which, tho' at firſt pleaſant, would, at a certain juncture of time, make one who held it in his mouth, think it had been imbued with garlic. And a perſon famous for making good cyder complain'd to me, that having among other trials, put into a veſſel full of juice of apples, a certain proportion of muſtard-ſeed, in hopes it would make the cyder more ſharp and ſpirituous, he found it ſmell ſo rank of garlic, that every body rejected it. I remember alſo, that by fermenting a certian proportion of *Semen Dauci* with ale, the liquor had a very pleaſant reliſh of lemmon-peel. But it ſeems much more conſiderable, that with an inſipid metal, and a very corroſive menſtruum, a taſte may be compounded, ſo like a vegetable, as to deceive many. This may be done by diſſolving gold, without any groſs ſalt, in a mixture of *Aqua fortis*, and the ſpirit of ſalt, or even in common *Aqua regis*, made by diſſolving ſal-armoniac in *Aqua fortis*. For if the experiment be happily made, there will be obtain'd, either a ſolution, or a ſalt, whoſe auſtere taſte very much reſembles that of ſloes, or unripe bullace. And this taſte, with ſome little variety, I found in gold diſſolved without any diſtilled liquor at all; and alſo, in gold, which by a peculiar menſtruum I had volatilized. The next inſtance, I found to have been known to ſome ingenious ladies. But to make the experiment ſucceed very well, a due proportion is the principal circumſtance, which is uſually neglected. I cannot call to mind that which I found to ſucceed beſt, but the trial may be indifferently well made, after this manner. Take a pint of malaga or canary, and put into it a dram or two of good orrice roots, cut into thin ſlices, and let them infuſe in the liquor for a convenient time, till you perceive it has gain'd the deſired taſte

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chineal, was taken for good raiberry-wine.

13. It will not perhaps be unacceptable to add a word or two, on this occaſion, for their ſakes, who think the maturation of fruit, and the changes of taſtes, by which it is uſually known, are the effect of the vegetable ſoul of the plant. For, after the fruit is gathered, and being no longer a part of the tree, ceaſes, according to the moſt common opinion, to be a part of the living plant, it belonged to; yet it is very poſſible, that ſome fruits may receive maturation, after they have been ſever'd from the plants that bore them. Apples, pluck'd too ſoon, uſually obtain a mellowneſs by lying in heaps; which ſeems to be a kind, or degree of maturation; and medlars, gathered whilſt they are hard and harſh, afterwards become ſoft, and better taſted. 'Tis alſo aſſerted by ſeveral writers of the affairs of *India*, that the fruit, they call *Bananas*, is uſually gathered green, and hung up in bunches, in the houſe, where they ripen by degrees, and have an advantageous change made both of their colour and taſte. And this experiment, an ancient acquaintance of mine aſſured me, he had himſelf lately tried, and found to be true, in *America*. And indeed, I ſee not why a convenient degree of warmth, whether external from the ſun and fire, or internal from ſome degree of fermentation, or analogous inteſtine commotion, may not put the ſapid corpuſcles into motion, and cauſe them, by various and inſenſible tranſcurſions to rub againſt each other, and thereby make the little bodies more ſlender and thin, leſs rigid or cutting, than they were before; and by various motions bring the fruit they compoſe to a ſtate, wherein it is of a more ſoft conſiſtence, and abounds in corpuſcles leſs harſh, and more pliable, than formerly, and better fitted to the pores of the organ of taſte; and, in a word, make ſuch a change in the conſtitution of the fruit, as we expreſs by the name of maturity. And that ſuch mechanical changes of texture may much alter the qualities, and among them, the taſte of a fruit, is obvious in bruiſed cherries and apples, which, in the contuſed parts, ſoon come to look and taſte otherwiſe than they did before. The poſſibility of this is alſo obvious from warden pears, gently roaſted in embers. And I have ſeen in the country between *France* and *Savoy*, a ſort of pears, which, being kept for ſome hours in a moderate heat, in a veſſel exactly cloſed, with embers and aſhes above and beneath them, will be reduced to a juicy ſubſtance, of a lovely red colour, and a very ſweet luſcious taſte. Many other ſorts of fruit, in different countries, if they were managed after the ſame way, would admit of as great alterations in point of taſte. And that more ſtubborn ſalts, than thoſe of vegetables, may have the ſharpneſs of their taſtes very much abated, by the bare internal action of one part upon the other, I have been induced to think, from obſerving, that by the help of inſipid water, we may reduce ſea-ſalt into a brine,

Some changes made of taſtes by maturation.

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PHYSICS. brine, of ſo mild and peculiar a taſte, that one would ſcarce ſuſpect what it had been; or believe, that ſo great a change of a mineral body could be effected by ſo ſlight and inteſtine commotion as produced it. As to vegetable liquors, the production of new taſtes upon the inteſtine commotions of the ſapid parts, is obvious in the juice of grapes, which, from a ſweet and ſpiritleſs liquor, acquires that pleaſing pungency and briſkneſs of taſte, which belongs to wine; and afterwards degenerates into that acid and cutting taſte, proper to vinegar; and all this from a change of conſtitution, made by the action of the parts themſelves, one upon another, without the help of any external addition.

SECT. II.

The mechanical production of odours.

SInce taſtes and odours are uſually treated of immediately after one another, I ſhall alſo conſider theſe two qualities ſucceſſively; becauſe much of what is already ſaid of taſtes, being applicable to odours, will ſave the trouble of repetitions.

A ſtrong ſmell produced by two ſcentleſs bodies.

1. Grind good quick-lime and ſal-armoniac well together, and holding your noſe to the mixture, you will find an urinous ſmell, produced by the particles of the volatile ſalt, which will alſo make your eyes water.

A ſtrong ſcent produced by water in a body, which had none before.

2. If a large proportion of camphire be diſſolved in oil of vitriol, the odour of the gum will be quite concealed in the mixture; but if you pour this mixture into a large quantity of fair water, the diſſolved gum will immediately recover out of the menſtruum, and ſmell perhaps more ſtrongly than before.

Produced odours differing from that of any of the ingredients.

3. Having cautiouſly mixed two parts of clear oil of turpentine, with one part of the oil of vitriol, the clear liquor that came over upon diſtillation of the mixture, inſtead of turpentine, ſmelt very ſtrong of ſulphur; ſo that once approaching very haſtily to the receiver, newly taken off from the retort, the ſulphureous ſcent proved ſo ſtrong, as almoſt to take away my breath. And farther, to ſhew the poſſibility of producing ſuch odours upon the mixtures of ingredients, as neither of them was a-part endowed with, we cauſed the ſubſtance that remained behind, in the retort, in the form of a thin extract, after one of theſe diſtillations, to be farther urged by a ſtronger fire, which forced moſt of it over, partly in the form of a thick oil; and partly in that of butter; both which we kept together in the ſame vial; their odour being neither that of oil of turpentine, nor of brimſtone; but exceedingly like the diſtilled oil of bees-wax.

4. That

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them, as to render them perceptible by the ſenſe, may be gathered from ſome common obſervations. Several bodies are not only inodorous when cold, but when conſiderably hot; and tho' they remain fixed in the fire, yet, having their parts put into a peculiar kind of agitation, they will preſently grow manifeſtly odorous. Some very hard woods, acquire a ſtrong ſmell by the motion they may be expoſed to in a turner's lath, particularly the *Lignum Vitæ*; and ſome, whilſt the operation laſts, afford an unexpected odour. Having inquired concerning the ſcent of beech-wood, whilſt it is turning, I was informed, that it would emit well-ſcented effluvia; and it was affirmed to me by a workman, who had bought a great block of this wood, that when he came to turn it, there would iſſue out, not only a great ſcent, but ſuch a peculiar fragrancy, that one, who knew not whence it proceeded, would have concluded he ſmelt roſes.

tion of odours by local motion.

5. Take ſalt of tartar, and drop upon it either ſpirit of nitre, or a weak *Aqua fortis*, till all the efferveſcence ceaſes, and the liquor no longer works upon the alkali; and theſe, by a ſlow evaporation of the ſuperfluous moiſture, may be made to ſhoot into cryſtals, like thoſe of nitre; which, after you have, by rubbing with a dried cloth, freed from looſe adhering corpuſcles, reſemble ſalt-petre, both in other qualities, and in not being odorous; tho', if you diſtil them, or burn them on kindled coals, their fumes will quickly appear to abound with the fetid ſpirits, which make *Aqua fortis* ſo offenſive to the ſmell.

A ſcented body, by mixing with an inodorous one, deprived of all its ſmell.

6. What I ſhall next propoſe, is performed at the ſame time, the eleventh experiment of taſtes is made. For the liquor thereby produced, if it be well prepared, has not only a ſpicy taſte, but alſo a kind of aromatic and pleaſant ſmell. And I have of it now by me, which has, for ſome years, retained much of its former odour, tho' not ſo much of its taſte.

A pleaſant aromatic odour produced by putting a fetid body to another not ſweet.

7. To a pound of *Spaniſh* wine, we put ſome ounces of oil of vitriol; then keeping them, for a reaſonable time, in digeſtion, we obtained an odoriferous mixture. But this experiment is improved by that which follows.

A fragrant odour produced by two bodies, not well ſcented.

8. We took good oil of blue *Dantzick* vitriol, tho' the common will ſerve; and having put to it by degrees, an equal weight of ſpirit of wine totally inflammable, we digeſted them together for two, three, or four weeks, ſometimes much longer, and then with better ſucceſs; when we came to diſtil the mixture, we had a very fragrant ſpirit, which was ſometimes ſo ſubtile, that, tho' diſtilled in a tall glaſs, with a gentle heat, it would pierce the lute, and fill the laboratory with a ſenſible perfume: whence we learn, both how much thoſe ſpirituous and inflammable particles, which chymiſts call the vegetable ſulphur of wine, may work on, and enoble a mineral

By the addition of an inodorous body, a pleaſant and aromatic ſmell given to ſpirit of wine.

4

PHYSICS. ſulphur; and how much the new contextures made by digeſtion, may alter the odours of bodies, whether vegetable, or mineral. That alſo another conſtitution of the ſame matter, without any manifeſt addition or receſs of particles, may exhibit a very differing ſmell, will appear by the following trial.

The fore-mentioned fragrant body, brought to ſmell like garlick.

9. I have more than once put the above-mentioned liquor into ſtopp'd glaſſes, whereof the one, and not the other, ſtood in a warm place, till, in proceſs of time, I found that odoriferous liquor ſo to degenerate in point of ſcent, that one would have thought it had been ſtrongly infected with garlick. The like unpleaſant ſmell I obſerved in a certain oil, made of vegetable and mineral ſubſtances diſtilled together. And on this occaſion, may be added an obſervation, which, tho' I ſhall not undertake it will always hold good; yet ſhews, that a body, which it ſelf is not only inodorous, but very fixed, may, in ſome caſes, have a great ſhare *in the phenomena* of odours. We put, then, to good ſalt of tartar, ſeveral times its weight of the expreſſed juice of onions, and kept them in a light digeſtion for a day or two; when unſtopping the vial, we found the former ſmell of the onions quite degenerated into a rank ſmell of garlick, as we judged, even when freſh juice of garlick was compared therewith.

The ſmell of muſk produced with an inodorous body, and another not well ſcented.

10. By caſting into ſpirit of vitriol, a large proportion of ſmall pearls unbroken; the action of the acid menſtruum upon them being moderated by its weakneſs, and by the intireneſs of the pearls, the diſſolution would ſometimes laſt for many hours; when, holding my noſe, from time to time, to the open orifice of the glaſs, it was eaſy to perceive a pleaſant muſky ſmell, which others alſo took notice of. And I obſerved the like ſmell, upon pearls, being diſſolved not only in ſpirit of vinegar, but in another liquor, which had but a bad ſcent of its own.

Pleaſant ſcents produced with fixed metals, and fetid or ſcentleſs bodies.

11. That gold is too fixed a body to emit any odour; and that *Aqua regis* has an odour, which is very ſtrong and offenſive, will be eaſily granted; yet *Aurum fulminans* being made by precipitating with the inodorous oil of tartar, the ſolution of the former in the latter, and this precipitate being to be farther treated, in order to another experiment, we fulminated it *per ſe*, in a ſilver veſſel, like that, but better contrived, which is deſcribed by *Glauber:* and among other phenomena of this operation, we obſerved, that when the fulmination was juſt made, the ſteams afforded by the metal, which had been fired, gave a delightful ſmell, not unlike that of muſk. From which experiment, and the foregoing, we learn, that art, by lucky contextures, may imitate the odours, which are preſumed to be natural and ſpecific; and that mineral and vegetable ſubſtances may compound a ſmell, which is thought peculiar to animals. And as art ſometimes imitates nature in the production of odours, (as may be confirmed by what is above related concerning counterfeit raſberry-wine; for thoſe, who drank it, believed they did not only taſte, but ſmelt

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ſmelt the raſberry ;) ſo ſometimes nature ſeems to imitate herſelf, in giv- PHYSICS.
ing like odours to bodies extremely differing. There is a certain ſeed, which, for the affinity of its odour to that perfume, they call the muſk-ſeed ; ſome of which being preſented me from the *Weſt-Indies*, I found it, whilſt freſh, to have a fragrancy ſuitable to the name, that was given it. There is, alſo, a ſort of rats in *Muſcovy*, whoſe ſkins have a ſmell, which has procured them the name of muſk-rats. And I have ſeen a certain ſort of ducks, call'd muſk-ducks; becauſe at a certain ſeaſon of the year, if they are chaf'd by violent motion, they will, under the wing, emit a muſky, inſtead of a ſweaty ſcent ; which, upon trial, I found true. On the other ſide, I have known a certain wood, growing in the *Indies*, which, eſpecially when the ſcent is excited by rubbing, ſmells ſo rankly, and ſo like human dung, that one would ſwear that were held under his noſe.

Tho' the fire generally impreſſes a ſtrong offenſive ſmell, which chymiſts, therefore, call empyreumatical, upon the odorous bodies it works ſtrongly on ; yet the conſtitution of a ſubſtance may be ſuch, that the new texture made of its parts, even by a violent fire, ſhall be fit to afford effluvia, rather agreeable to the organs of ſmelling, than any way offenſive. Having diſtilled *Saccharum Saturni* in a retort, with a ſtrong fire, I obtained, beſides a piercing and empyreumatical liquor, which was driven over into the receiver, a large lump of *Caput mortuum* of a greyiſh colour, which, notwithſtanding the ſtrong impreſſion it receiv'd from the fire, had a pleaſing ſcent, and, when broken, ſmelt almoſt like a fine cake new baked, and broken whilſt yet warm. And as the fire, notwithſtanding the empyreuma it uſually gives to almoſt all the bodies it burns, may yet confer a good ſmell on ſome of them, if they be fitted, upon ſuch a contexture of their parts, to emit ſteams of ſuch a nature ; we obſerve in the muſk-animal, that nature, in that cat, or rather deer, produces muſk by ſuch a change, as, in other animals, produces a putrefactive ſcent. So that, provided a due conſtitution of parts be introduced into a portion of matter, it may, on that account, be endowed with noble, and deſirable ſcents, or other qualities ; tho' that conſtitution were introduced by ſuch unlikely means, as combuſtion or putrefaction. An eminent profeſſor of mathematics affirmed to me, that chancing one day, with another mathematician, in the heat of ſummer, to paſs by a large dunghil, which was then in *Lincolns-Inn-Fields* ; when they came within a certain diſtance of it, they were both ſurprized to find a very ſtrong ſmell of muſk ; which each, for ſome time, was ſhy of taking notice of, for fear the other ſhould have laughed at him : but when they came much nearer the dunghil, that pleaſing ſmell was ſucceeded by a ſcent, proper to ſuch a heap of excrements. And indeed, tho' the excrements of animals, and particularly their ſweat, are uſually fetid ; yet, that this is not the nature of an excrement, but the conſtitutions uſually belonging to them, which make them ſo, hath

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PHYSICS. ſeemed probable to me from ſome obſervations. For, not to mention what is related of *Alexander* the great, I knew a gentleman of a very happy temperature of body, whoſe ſweat, upon a critical examination, I found to be fragrant; which was alſo confirmed by ſome learned men of my acquaintance, and particularly, by a phyſician, who lay with him. Tho' civet uſually paſſes for a perfume; yet it ſeems to be but a clammy excrement of the animal that affords it, which is ſecreted into bags, provided by nature to receive it. And upon ſeeing ſeveral of theſe civet-cats; I obſerved, that a certain degree of remiſſneſs in the odorous atmoſphere was requiſite to make the ſmell fragrant. For when I have been near the cages, where many of them were kept together, or any great veſſel, full of civet, the ſmell was rather rank, and offenſive, than agreeable; but when I removed to a convenient diſtance, the ſteams being leſs crowded, and farther from their fountain, preſented themſelves as a perfume. *And an ingenious lady ſhewed me an odd monky, which had been preſented her, as a rarity, by the Engliſh admiral*; telling me, amongſt other things, ſhe had obſerved in it, that, being ſick, he would ſeek for ſpiders, as his proper remedy; which when he had eaten, the alteration it made in him, would ſometimes fill the room with a muſky ſcent.

Good ſmells heighten'd by compoſition.

12. It is well known to perfumers, that amber-greaſe alone, tho' eſteemed the beſt and richeſt perfume in the world has but a very faint and ſcarce pleaſant ſcent. And I have ſeen ſome hundreds of ounces together, newly brought from the *Eaſt-Indies*; but if I had not been before acquainted with the ſmell of amber-greaſe in the lump, my noſtrils would ſcarce have made me ſuſpect thoſe lumps to have been any thing of kin to amber-greaſe. This amber-greaſe is, if I am rightly inform'd, a vegetable production, iſſuing out of the root of a tree, which always ſhoots its root towards the ſea: and if it be planted where the ſteam ſets to the ſhore, 'twill be caſt up to great advantage. But if a due proportion of muſk, or even civet, be dextrouſly mixed with amber, the latent fragrancy, tho' it be thereby ſomewhat compounded, will be quickly called out, and exceedingly heightened. And indeed, it is not the great quantity of the richeſt ingredients, as amber-greaſe and muſk, but the juſt proportion and ſkilful mixture of them, that makes the nobleſt, and moſt laſting perfume; of which I have had ſufficient experience: ſo that with a far leſs quantity of muſk and amber than perfumers themſelves employ, we have had ſeveral perfumes, which, for fragrancy, were much preferr'd to thoſe, where muſk and amber-greaſe are ſo plentifully uſed. The beſt proportion for their mixture ſeems to be eight parts of amber-greaſe, two of muſk, and one of civet; which quantities of ingredients, if ſkilfully and exactly mixed, will afford a good compoſition, wherewith to enoble other materials, as benzoin, ſtorax, *&c.* fit to make paſtils, ointments for leather, *&c.* We may add, that upon account of the new texture, acquired by compoſition, ſome things, which are not fragrant themſelves, may much heighten the fragrancy of odoriferous bodies. And for liquid perfumes, I remember it was the ſecret of ſome court-ladies, noted for curioſity in perfuming, to mix always

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accuſtomed to choice perfumes. This liquor, tho' thought an elaborate preparation, and which, to recommend it to ſuch whoſe critical palates can taſte the very titles of things, I called eſſence of muſk, is, indeed, a very plain ſimple preparation, which I thus make. I take any quantity of choice muſk, without finely powdering it, and pour thereon about a finger's breadth of pure ſpirit of wine; I ſet theſe, in a glaſs cloſely ſtopped, in a quiet place to digeſt, without the help of any furnace, and after ſome days, or a few weeks, the ſpirit will, in the cold, have made a ſolution of the fineſt parts of the muſk, and be thereby much tinged, but not of a red colour. This being decanted, I keep by it ſelf as the richeſt of all; and pour like quantity of ſpirit on the remaining muſk; and this, too, ſually will, in the cold, tho' more ſlowly, draw a tincture, but fainter than the former, which being poured off, the remaining muſk may be employed for inferior uſes. I mention this preparation, becauſe the firſt tincture, being ſmelt to by it ſelf, has but a faint, and no very pleaſing odour of muſk; ſo that every one wou'd not expect there was muſk in it: but if a ſingle drop were mixed with a pint, or perhaps with a quart of ſack, the whole body of the wine would preſently acquire a conſiderable muſky ſcent, and be ſo richly perfumed, both in taſte, and ſmell, as ſeemed ſtrange to thoſe, who knew the vaſt diſproportion of the ingredients.

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THE MECHANICAL ORIGIN OF HEAT and COLD.

SECT. I.

The origin of cold mechanical.

HEAT and cold being generally eſteem'd the moſt active among qualities, from which ſeveral others are deducible, and by which many phenomena of nature are explicable; it will be proper to ſhew how they may either be mechanically produced or deſtroyed.

To produce a great degree of coldneſs, at any time of the year.

1. To produce a conſiderable degree of cold at any time of the year, without ſnow, ice, hail, wind, or nitre, take one pound of powdered ſal-armoniac, and about three pounds of water; put the ſalt into the liquor either all together, if you would produce an intenſe ſhort coldneſs; or at three or four times, if you deſire, that the cold ſhould rather laſt ſomewhat longer than be great; ſtir the powder in the liquor, with any thing that will not be injur'd by the fretting brine, to haſten the diſſolution of the ſalt; upon the quickneſs of which very much depends the intenſeneſs of the cold, that will enſue upon this experiment.

That a conſiderable degree of cold is here produced, will evidently apear to the touch; and if you make the experiment in a glaſs body, you may obſerve, that while the ſalt diſſolves, the outſide of the veſſel will, as high as the mixture reaches, be bedewed with a multitude of little drops of water; as happens when mixtures of ſnow and ſalt, being put into glaſſes, the aqueous vapours that float in the air, and paſs along the ſides of the veſſel, are, by the coldneſs thereof, condenſed into water. And in our ſolution you may obſerve, if you wipe off the dew from any particular part of the outſide of the veſſel,

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ſel, whilſt the ſolution goes vigorouſly on, it will quickly collect freſh dew, which will ſometimes be large enough to run down the ſides of the veſſel. But the beſt and ſureſt way of proving the coldneſs of the mixture, is by plunging into it a good ſealed weather-glaſs, furniſh'd with tinged ſpirit of wine: for the ball of this, being put into our frigorific mixture, the crimſon liquor will ſuddenly deſcend much lower, than when it was kept either in the open air, or in common water, of the ſame temper with that, wherein the ſal-armoniac was put to diſſolve. And if you remove the glaſs out of our mixture into common water, the tinged ſpirit will aſcend, according to the longer or ſhorter time, that it continued in the ſolution. And this hath ſucceeded, when, inſtead of removing it into common water, I removed it into water newly impregnated with ſalt-petre. PHYSICS.

The duration of the cold produced by this experiment, depends on ſeveral circumſtances, as, 1. The ſeaſon of the year, and the preſent temper of the air; for in ſummer and hot weather, the cold will ſooner decay and expire. 2. Upon the quantity of ſalt and water; for if both theſe be great, the effect will be more laſting and conſiderable: 3. We may, probably, add the goodneſs and fitneſs of the ſalt employed; for ſome trials have tempted me to ſuſpect, that there may be a conſiderable diſparity, as to their fitneſs to produce cold, betwixt parcels of ſalt that are, without ſcruple, taken for ſal-armoniac. 4. The duration of the cold may be conceived to depend, alſo, upon the way of putting the ſalt into water. I have often tried, that when the tinged ſpirit ſubſided but ſlowly, or was at a ſtand, that by putting in, from time to time, two or three ſpoonfuls of freſh ſalt, and ſtirring the water, the ſpirit of wine would again deſcend much more ſwiftly. And if you would lengthen the experiment, let part of the ſal-armoniac be but groſly beaten, that it may be the longer in diſſolving. Whilſt dewy drops are produced on the outſide of the veſſel, it's a ſign that the cold within continues pretty ſtrong; for when it ceaſes, theſe drops, eſpecially in warm weather, will, by degrees, vaniſh. But a ſurer way of meaſuring the duration of the cold is, by removing, from time to time, the ſealed weather-glaſs, out of the ſaline mixture into the ſame common water, with part of which it was made. I have in the ſpring-ſeaſon, by a good weather-glaſs, found a ſenſible adventitious cold, made by a pound of ſal-armoniac, to laſt about two or three hours.

March 27. In the ſealed weather-glaſs, when firſt put into the water, the tinged ſpirit reſted at $8\frac{1}{4}$ inches; being ſuffered to ſtay there a good while, and now and then ſtirred in the water, at length it deſcended a little beneath $7\frac{1}{4}$ inches; then the ſal-armoniac being put in, within about a quarter of an hour, or a little more, it deſcended to $2\frac{1}{16}$ inches; but in half a quarter of an hour, it began manifeſtly to freeze the vapours and drops of water on the outſide of the glaſs. And when the frigorific power was arrived at its height, I, ſeveral times,

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PHYSICS. times, found, that water thinly placed on the outside, whilst the mixture within was nimbly stirred, would freeze in a quarter of a minute. At about ½ of an hour after the infrigidating body was put in, the thermometer, that had been taken out a while before, and was yet risen but to the lowest freezing mark, being again put into the liquor, fell an inch below the mark. At about 2½ hours from the first solution of the salt, I found the tinged liquor to be in the midst between the freezing marks, whereof there was one at 5½ inches (at which height when the tincture rested, it would usually be a small frost abroad) and the other at 4⅙ inches; the height to which strong and durable frosts had reduced the liquor in the winter. Within three hours after the beginning of the operation, I found not the crimson liquor higher than the upper freezing mark, just mentioned; after which, it continued to rise very slowly, for about an hour longer. The frigorific mixture, having been made in a glass body, with a large flattish bottom, a quantity of water, purposely spilt upon the table, was, by the operation of the mixture within the glass, made strongly to freeze the bottom of the cucurbite to the table; that stagnant liquor being turned into solid ice, which continued for a considerable while unthawed, and was, in some places, about the thickness of a half-crown piece.

At another time, during the same spring, the sealed weather-glass, which before it touched the common water, stood at 8⅒, having been left there a considerable while, and once or twice agitated in the water, the tinged liquor sunk but to 7⅒, or at the farthest 7⅘; then the frigorific liquor being put into the water, with disadvantageous circumstances; in about half a quarter of an hour, the tinged liquor fell beneath 7¼; and the thermometer being taken out, and put in again, an hour after the water had been first cooled, subsided beneath five inches, and consequently was within ¼ inch of the mark of the strongly freezing weather.

The grand thing, likely to keep this experiment from being generally useful in cooling liquors, *&c.* is the dearness of sal-armoniac, which might come much cheaper, if, instead of fetching it from beyond sea, we made it at home; which may be easily done. And tho' a solution of sal-armoniac, being boiled up in earthen vessels, (glass ones being too chargeable) will lose the more subtile parts, and thereby impair the texture of the rest; yet I have found, that the dry salt, remaining in pipkins, being dissolved in a due proportion of water, would very considerably infrigidate it.

March 29. The thermometer, that in the air was at 8¼ inches, being put into a large evaporating glass, filled with water, fell, (after it staid a pretty while, and had been agitated in the liquor) to eight inches; and then about half the salt, or less, that had been used twice before, and felt much less cold than the water, being put in, and stirred about, the tinged spirit subsided till it was fallen beneath four

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the ſpirit of wine manifeſtly to aſcend in the inſtrument, much faſter than one would have expected. The cool liquors with this mixture, put them into thin glaſſes; and their orifices being ſtop'd and kept above the mixture, move them about therein, and then pour them out for drinking. By means hereof pieces of cryſtal, or bullets, may be powerfully cooled, to be held in the mouth or hands of thoſe patients who require them; or other the like refreſhment may be eaſily procured, with a very few ounces of ſal-armoniac, well powder'd and ſuddenly diſſolved in four times its weight of water *.

A coldneſs produced by the mixture of warm bodies.

2. And to ſhew that a more intenſe degree of cold may reſult from the mixture, than was to be found in either of the ingredients apart; and alſo that a conſiderable coldneſs may be begun between bodies, neither of them actually cold before they were put together; having brought a glaſs full of water to ſuch a temper, that its warmth made the ſpirit of wine in the ſealed weather-glaſs, manifeſtly aſcend, I took out the thermometer, and laid it in powdered ſal-armoniac, warmed before hand; whereby the tinged liquor was made to aſcend much quicker than, juſt before, by the water; and having preſently removed the inſtrument into that liquor again, and poured the warmiſh ſal-armoniac into the ſame, I found, that within half a minute, or leſs, the ſpirit of wine began to ſubſide, and fell above a whole diviſion and a quarter, below the mark at which it ſtood in the water, before that liquor or the ſalt were warmed. Nor did the ſpirit, in a great while, re-aſcend to the height it had when the water was cold. The ſame experiment we made at another time with the like ſucceſs.

3. To ſhew, likewiſe, how much the production of heat and cold depends upon texture, and other mechanical properties, I made a ſal-armoniac after a particular manner, that I might know the effects of the ingredients, as well before, as after conjunction. I took, then, ſpirit of ſalt, and ſpirit of fermented, or rather putrefied urine; and having put a ſealed weather-glaſs in an open veſſel, into which one of them was poured, I added the other, by degrees, to it; and obſerved, that, as upon mixing, they made a great noiſe, with many bubbles, ſo in the conflict, they loſt their former coldneſs, and impelled up the ſpirit of wine in the ſealed thermometer; then, ſlowly evaporating the ſuperfluous moiſture, I obtained a fine ſort of ſal-armoniac, for the moſt part figured not unlike the other, when, being diſſolv'd, and filtred, it is carefully coagulated. This new ſalt being gently dried, I put it into a wide glaſs of water, wherein I had before placed a ſealed

* For a great degree of cold produced by mercury-ſublimate, ſal-armoniac, and diſtill'd vinegar; with many other cold diſſolutions and fermentations, with the mechanical account of them, See *Philoſ. Tranſ.* N°. 274. p. 951. and the *French* Memoirs. *A.* 1700. p. 142.

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PHYSICS. weather-glaſs, that the included ſpirit might acquire the temper of the ambient liquor; and having ſtirred this ſalt in the water, tho' I took it then off the mantle-piece of a chimney, wherein there had been a fire for ſeveral hours before, it made the tinged ſpirit haſtily ſubſide.

Heat produced by the mixture of cold bodies. 4. We took a ſmall ſeal'd thermometer, whoſe ſtem was divided into equal parts, by little ſpecks of amel, that ſharp liquors might not eat off or ſpoil the marks. The ball of this inſtrument we put into a ſlender cylindrical veſſel, and more than cover'd it with ſtrong oil of vitriol, and left it there a while to be reduc'd to the temper of the ſurrounding liquor. Then we caſt upon it, by degrees, ſal-armoniac groſly powder'd, which being ſoon furiouſly wrought on by the menſtruum; a ſeeming effervescence was produced in the conflict, with great noiſe and much froth, which more than once was ready to run out of the veſſel. But for all this ſeeming ebullition, the mixture, inſtead of growing hot, did really grow gradually colder, as appear'd not only to the touch, but by the deſcent of the tinged ſpirit of wine. But pouring this actually cold mixture into three or four times its weight of common water, that was likewiſe actually cold; this ſecond mixture immediately grew ſo hot, that I cou'd not keep my finger for a minute or two upon the outſide of the containing glaſs.

Ebullition no argument of heat. 5. We took an acid ſpirit, diſtilled from roch-alum, and put into a wide-mouth'd glaſs, more than was ſufficient of it to cover the globular part of a good ſeal'd thermometer; then ſuffering the inſtrument to remain for ſome time in the liquor, to acquire the temper thereof, we put in, by degrees, ſome volatile ſalt; ſublimed from ſal-armoniac and a fixed alkali; when, notwithſtanding the very numerous bubbles, and the noiſe and froth which were produced, as is uſual upon the re-action of acids and alkalies, the tinged ſpirit in the weather-glaſs began a little to deſcend, and continued to do ſo, till the ſpirit of alum was glutted with the volatile ſalt; the deſcent of the tinged liquor in the inſtrument amounting to an inch. By comparing this experiment with the firſt part of the third, it appears, that when volatile and urinous ſalts or ſpirits tumultuate upon their mixture with acids; neither the heat nor the cold, which enſues, is produced by a conflict with the acids, merely upon account of their acidity; ſince we have ſeen, that an urinous ſpirit produced an actual heat with ſpirit of ſalt; and the diſtilled ſalt of ſal-armoniac, which is alſo urinous, with the acid ſpirit of roch-alum, produces not a true effervescence, but a manifeſt coldneſs: as the ſame ſalt alſo did in a trial of another ſort, which was this.

6. We took one part of oil of vitriol, and ſhaking it into twelve parts of water, made a mixture, which at firſt was ſenſibly warm; then ſuffering it to cool, we put a ſufficient quantity thereof, into a wide-mouth'd glaſs, and placed in it a good thermometer hermetically ſealed; the compound liquor, reaching a pretty way above its ball: after ſome time had been allow'd, for the liquor in the thermometer to acquire the temper of the external one; we gradually put in as much volatile ſalt of ſal-armoniac, as ſatiated the acid ſpirits of the mixture.

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ture. Now though these two made a notable conflict with noise and froth, yet it was but a cold ebullition; for the spirit in the thermometer descended about an inch beneath the mark it rested at, when the seeming effervescence began. PHYSICS.

7. It is known that salt-petre being put into common water, produces a sensible coldness therein, as it doth also in many other liquors; but that the same salt, put into a liquor of another constitution, may have a quite different effect, appears by mixing eight ounces of fine salt-petre in powder, with six ounces of oil of vitriol: for here a salt, not only actually cold, but, with regard to many other bodies, potentially so, with the oil of vitriol, which is sensibly cold too, quickly conceives a considerable degree of heat, whose effects also become visible in the plenty of fumes, emitted by the heated mixture. And tho' gun-powder seems to be of a very fiery nature, yet if some ounces of it, reduced to powder, be thrown into four or five times as much water, it will very manifestly impart a coldness to it; as experience made with, as well as without, a sealed thermometer has assured me. This, and the foregoing experiment, suggests an inquiry into the nature of the coldness, which philosophers oppose to that which immediately, and upon the first contact, affects the organs of sense; and which, therefore, they call actual or formal. We repeated the former experiment with the same success; and the phenomenon is the more strange, because I have found, that a small quantity of oil of vitriol, not beforehand mixed with water, would produce a great heat in its conflict with a small portion of just such salt as I employ'd before: and this heat did, upon trial, with the same thermometer, make the tinged spirit ascend much farther than the other mixture made it subside. *The same body that cools some liquors may heat others.*

8. Potential coldness has been generally look'd upon as so abstruse a quality, that it seem'd necessary to derive it from the substantial forms of bodies. But I think it may be ascrib'd to mechanical properties. For as to the chief instances thereof, which are taken from the effects of some medicines and aliments in the human body, the coldness produc'd, may proceed chiefly from hence, that the body potentially cold, is made up of corpuscles of such size, shape, *&c.* that being dissolved, and disjoined by the menstruum of the stomach, or the fluids it may elsewhere meet with, they so associate themselves with the small parts of the blood, and other liquors, as by clogging them, or otherwise, to cause them to act in a peculiar way, and more slowly, on the nervous and fibrous parts: and the perception of this imminution of motion in the organs of feeling is that, which, being referred to the body producing it, we call its potential coldness. Which quality hence appears to be but a relative thing, and to require the diffusion of the small parts of the corpuscles of the agent, and their mixture with the liquors, or the small parts of the body they are to cool. And therefore, if it be granted that there is in agues, some morbific matter of a viscous, or not easily dissipable texture, harboured in some part of the body, which requires a determinate time to be made *Potential coldness.*

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PHYSICS. fluid, and reſolvable; the cold fits of agues need not appear ſurprizing; ſince, tho' juſt before the fit, the ſame parcel of matter, which is to produce it, was actually in the body; yet it was not, by reaſon of its clammineſs, actually reſolved into ſuch parts, and mixed with thoſe of the blood; and conſequently could not make ſuch a change in the motion of that fluid, as is felt in the cold fit of an ague. And in ſome other diſeaſes, a ſmall quantity of matter, being reſolved into minute parts, may produce a great ſenſe of coldneſs in a particular part of the body, which, by reaſon of its ſtructure, may be peculiarly diſpoſed to be affected thereby; as hyſterical women complain of great coldneſs, which ſuddenly invades ſome particular part, as the head or back, and long continues to be troubleſome there. And that, if a cold vapour or matter be exceeding ſubtile, an inconſiderable quantity of it, being diſperſed through the blood, may produce a great degree of coldneſs, appears from the effects of ſome poiſons. And it is not very material, whether the poiſon, generally ſpeaking, be hot or cold, if it meets with a body diſpoſed to have thoſe affections, which paſs for cold ones, produced in it. For I have made a chymical liquor, which, tho' fiery upon the palat, and poſſeſs'd of a briſkneſs and a ſubtilty from diſtillation, given in the quantity of a ſingle drop, wou'd immediately caſt an animal into that which appear'd a ſleep; and the like liquor, in the like quantity, being by miſtake applied to an aching tooth, preſently gave an univerſal coldneſs and trembling to the body, worſe than the cold paroxyſm of a quartan. And tho' ſcorpions, by their ſting, ſometimes cauſe violent heats in the parts they hurt, yet ſometimes alſo, their poiſon proves in a high degree potentially cold, as may be learn'd from the two following obſervations, of eminent phyſicians. "I had a ſervant," ſays *Benivenius*," who being ſtung by a ſcorpion, im-" mediately afterwards fell into ſo cold a ſweat all over his body, that " he complain'd he was every way cover'd with ice and ſnow. But he was " preſently relieved from it, and cured by a doſe of *Venice* treacle given in " ſome ſtrong wine." And *Amatus Luſitanus* tells us of a man ſtung in the finger by a ſcorpion, whence great pain enſued, with an univerſal coldneſs and trembling, and the ſenſe, as it were, of needles pricking his whole ſkin.

Perhaps in theſe great refrigerations, there may be ſome ſmall concretions or coagulations made of the minute particles of the blood into little clots, more unwieldy than they were, when ſeparately moved; as happens in the little curdlings, made of the parts of milk, by a very ſmall proportion of ſome acid liquor; or in the ſmall coagulations made of the ſpirit of wine by that of urine. Perhaps alſo beſides the ſlackening of the circulation of the blood, ſome poiſons, and other analogous agents, may give the motion of it a new modification, and thereby cauſe it to grate, or act in a peculiar manner upon the nervous and fibrous parts of the body. And, as ſome parts of the human body greatly differ from others, in their ſtructure and internal conſtitution; and

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is applied; or perhaps, upon one or both of these accounts, be cold with respect to one part of the body, and hot in regard of another. And these effects need not be always ascribed to the mere, and immediate action of the corpuscles of the medicine, but sometimes to the new quality they acquire in their passage, by associating themselves with the blood, or other fluids of the body; or to the expulsion of some heating or cooling corpuscles; or to the disposition they give the part on which they operate, to be more or less permeated and agitated than before, by some subtile matter, or other efficients of heat or cold. Some of these conjectures, about the relative nature of bodies potentially cold, may be either confirmed or illustrated by such instances as these. Spirit of wine, internally taken, is potentially very hot, yet being outwardly applied to burns, and hot tumours, it considerably abates the heat of the inflamed parts; tho' the same spirit, applied even outwardly to a tender eye, will cause a great and painful agitation therein. And camphire, which, in the dose of less than half a scruple, has been observed to diffuse an heat thro' the body, is, with success, externally applied in cooling medicines. But I leave the farther enquiry into the operations of medicines to physicians, who may possibly, by what has been said, be assisted to reconcile the differences of writers about the temper of those medicines, as mercury, camphire, *&c.* which some will have to be cold, and others hot; and shall only offer a few particulars to shew, in general, that potential coldness is only a relative quality. The first is afforded by comparing the two last experiments together; whence it seems probable, that the same thing may be potentially cold to one body, and not to another, according to the disposition of the body whereon it operates, or that operates upon it. The fumes of lead have been sometimes observed to arrest the fluidity of mercury, which change is supposed to be the effect of a potential coldness, belonging to lead, with regard to fluid mercury, tho' it have not that operation on any other liquor, that we know of. And lastly, tho' nitre, and sal-armoniac, be both apart, and jointly cold, with respect to water; and tho' nitre, however throughly melted in a crucible, will not of it self take fire, yet if, whilst it is in fusion, you, by degrees, cast on it some powdered sal-armoniac, it will take fire, and flash vehemently, almost as if sulphur had been thereon injected.

9. To twelve ounces of sal-armoniac, we put, by degrees, an equal weight of water; and whilst the liquor dissolved the salt, and by that action produced a great coldness, we warily poured in twelve ounces of good oil of vitriol; whence a notable degree of heat was quickly produced in the glass, wherein the ingredients were mixed; though it seem'd unlikely, that as each of the two

Heat produced by the joint action of two bodies upon a third, with which, separately, they produce cold.

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PHYSICS. two liquors usually, with sal-armoniac, produce an intense cold, that both of them acting on it together, should produce the contrary quality.

Heat and cold accidentally varied in their production.

10. In most of the experiments hitherto proposed, cold is regularly produced in a mechanical way; but in some sort of trials, I found the event varied by unobserved circumstances; so that manifest coldness would be sometimes produced by mixing two bodies together, which, at another time, would upon uniting disclose a manifest heat; and sometimes again, tho' more rarely, would have but a very faint degree of either. Of this sort of experiments I found to be the dissolution of salt of tartar in spirit of vinegar, and some other salts, which were not acid, in the same menstruum: and even the spirit of verdigrease, (made *per se*) tho' a more powerful menstruum, than common spirit of vinegar, would not constantly produce near such an heat at the beginning of its operation, as the greatness of the seeming effervescence, then excited, would induce one to expect. To eight ounces of spirit of verdigrease (wherein we had a while before put a standard-thermometer, to acquire the like temper with the liquor) we added in a wide-mouth'd glass two ounces of salt of tartar, as fast as we durst, for fear of making the liquor boil over; and tho' there was a great commotion excited by the action, and re-action of the ingredients, attended with a large froth, and a hissing noise; yet the glass did not soon become warm on the outside; but by that time the salt was all dissolved, the spirit in the thermometer appeared to have risen three inches and a half. On the other hand, I have found, that by mixing salt of tartar with another salt, the texture of the fixed alkali was so altered, that upon the affusion of spirit of verdigrease, tho' there ensued a great conflict with noise and bubbles, yet instead of heat, a considerable degree of coldness was produced.

11. It is very probable, that farther trials will furnish us with more instances, to shew how the production of cold may, in some cases, be effected, varied, or hinder'd by mechanical circumstances, which are usually overlooked. We observed, in the experiment lately mention'd, that tho' the oil of vitriol and water, being first shaken together, and the volatile salt of sal-armoniac, afterwards put to them, produced a sensible coldness; yet if a little oil of vitriol, and of the volatile salt were first put together, tho' soon after a considerable proportion of water was added, there would be produced not a coldness, but a manifest degree of heat, which impell'd the spirit in the thermometer to the height of some inches. I remember too, tho' salt of tartar grows hot in water, yet having distilled some of that, and cinnabar, in a strong fire, and put the whole *Caput mortuum* into distilled or rain-water, it made, indeed, an hissing there; as if it had been quick-lime, but produced no sensible heat. And not only some unheeded circumstances may promote or hinder the artificial production of cold by particular agents, but, perhaps, some hardly observable indisposition in the patient, may promote or hinder the effects of the grand, and universal efficients of cold;

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cold; for I have ſometimes found, that the degree of the operation of cold has been much varied by latent circumſtances; ſome bodies being more wrought upon, and others leſs, than we, upon very probable grounds, expected. And particularly, I remember, tho' oil of vitriol be one of the moſt fiery liquors yet known, performs ſome of the operations of fire it ſelf, and thaws ice, ſooner than ſpirit of wine, or any other liquor; yet having put about a pound of fine rectified oil of vitriol into a ſtrong glaſs-vial proportionable to it, we found that, except a little, which was fluid at the top, it was all congealed, or coagulated into a maſs, like ice, tho' the glaſs ſtood in a laboratory, where a fire was conſtantly kept not far from it, and where oil of vitriol very ſeldom, or never, has before, or ſince, been obſerved to congeal ſo much as in part. The oddneſs of our phenomenon was increaſed by this circumſtance, that the maſs continued ſolid, for a long time after the weather was grown too mild to have ſuch operations upon liquors, much more diſpoſed to loſe their fluidity by cold, than even common oil of vitriol. On the other hand, having expoſed ſome oil of ſweet almonds, hermetically ſealed up in a glaſs-bubble, to obſerve what condenſation an intenſe cold would make of it, (for tho' cold expands water, it condenſes common oil;) I found the next day, that not only the oil remained unfrozen by the ſharp froſt, whereto it had been expoſed; but that it had not its tranſparency diminiſhed, tho' it is known that oil will be brought to concrete by a far leſs degree of cold, than is requiſite to freeze water. This liquor, nevertheleſs, which was lodged in a glaſs, blown at the flame of a lamp, continued fluid, and tranſparent in very froſty weather ſo long, that I never expected to ſee it congealed. And tho' camphire is often reckoned potentially cold, yet ſome oil of it, wherein the whole body of the camphire remained, reduced by ſome nitrous ſpirits to that form, being kept in ſuch intenſe degrees of cold, that would have eaſily frozen water, it loſt not its tranſparency, or fluidity *.

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* The power of congelation is not always proportionable to the degree of cold, but ſeems, in ſome meaſure, to depend on other alterations in the weather; and actual cold ſeems not owing to a mere reſt of parts among themſelves; nor can hardneſs proceed from a mere deprivation of motion; whence it appears probable, ſince a mixture of certain ſalts with water give a great degree of coldneſs, and ſometimes, when the proportions have been nicely hit, turn it to ice, that a particular kind of ſalt is the cauſe of congelation, by inſinuating between the particles of water like nails, and fixing them together; tho' this is but a conjecture. See *Clark. Annot.* in *Rohault.* p. 117, 148.

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SECT. II.

Heat mechanically producible.

HEat will appear the more likely to be mechanically producible, from conſidering the nature of it. And this ſeems principally to conſiſt in that mechanical property of matter we call motion; which is ſubject to three conditions. Firſt, the agitation of the parts muſt be vehement; for this diſtinguiſhes the bodies ſaid to be hot, from thoſe which are barely fluid. Thus the particles of water, in its natural ſtate, move ſo calmly, that we do not feel it at all warm, tho' it could not be a liquor, unleſs they were in a reſtleſs motion; but when water comes to be actually hot, the motion manifeſtly, and proportionably appears more vehement; ſince it does not only ſtrike our organs of feeling briſkly, but ordinarily produces numerous very ſmall bubbles, melts coagulated oil caſt upon it, and affords vapours, which, by their agitation, aſcend into the air. And if the degree of heat be ſuch, as to make the water boil, then the agitation becomes much more manifeſt, by the confuſed motions, waves, noiſe, bubbles, and other obvious effects excited therein. Thus in a heated iron, the vehement agitation of the parts may be eaſily inferred from the motion, and hiſſing noiſe it makes with the drops of water, that fall upon it. And fire, which is the hotteſt body we know, conſiſts of parts ſo vehemently agitated, that they perpetually fly off in ſwarms, and diſſipate all the combuſtible bodies they meet with in their way; making ſo fierce a diſſolution, and great conſumption of its own fewel, that we may ſee whole piles of ſolid wood ſo diſſipated into flame, and ſmoke, that ſometimes there will not be one pound of aſhes remaining.

Agitation requiſite to heat.

And various determinations.

The ſecond condition is, that the determinations be very various, and tend all manner of ways. This variety of determinations appears to be in hot bodies, both by ſome of the inſtances already mentioned, and eſpecially that of flame, which is a body; by the diffuſion, which metals acquire, when melted; and by the operations of the heat, exerciſed by hot bodies upon others, in what poſture or ſituation ſoever the body, to be heated thereby, is applied to them. Thus a coal, thoroughly kindled, will appear on all ſides red, and melt wax, and kindle brimſtone, whether the body be applied to the upper, the lower, or to any other part of it. And according to this notion, tho' air and water be moved ever ſo vehemently, as in high winds, and cataracts, yet we are not to expect they ſhould thence become manifeſtly hot; becauſe the vehemence belongs to the progreſſive motion of the whole body; notwithſtanding which, the parts it conſiſts of may not be near ſo much accelerated in the motions, made according

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ing to other determinations, as to become ſenſibly hot. No wonder then, PHYSICS. that, in ſome caſes, where the whole body tends but one way, it is not perceived to be made hot thereby.

Nay, tho' the agitation be very various, as well as vehement, there is yet a third condition required, to make a body hot. For the agitated particles, or at leaſt, the greateſt number of them, muſt be ſo minute, as to be ſingly inſenſible. Were an heap of ſand to be vehemently agitated by a whirl-wind, the bulk of the corpuſcles would keep their agitation from being properly heat; tho' by their numerous ſtrokes upon a man's face, and the briſk commotion of the ſpirits, and other ſmall particles, which may thence enſue, they may perhaps produce that quality. *That the moving particles ſhould be ſmall.*

1. Hence, if we duly attend to this notion of the nature of heat, 'tis eaſy to diſcern, how it may, ſeveral ways, be mechanically produced. For, except in ſome few anomalous caſes, by whatever means the inſenſible parts of a body are put into a very confuſed and vehement agitation, heat will be introduced into that body. And as there are ſeveral agents and operations, by which this heating motion may be excited; ſo there muſt be ſeveral mechanical ways of producing heat. Various experiments may be reduced to almoſt each of theſe heads; chance it ſelf having, in the laboratories of chymiſts, afforded ſeveral phenomena, referable thereto. Many of the more familiar inſtances, applicable to this purpoſe, are collected by the Lord *Verulam*, in his excellent paper, *De formâ calidi*. There are ſeveral cauſes aſſign'd for the heat obſerved in quick-lime, upon the affuſion of cold water; which to me ſeem either juſtly queſtionable, or manifeſtly erroneous. The ſchools tell us, it happens by virtue of an antiperiſtaſis, or invigoration of the internal heat of the lime, upon its being ſurrounded by cold water: but this is an imaginary cauſe; for if the water be poured on very hot, the ebullition of the lime will not be the leſs, but rather greater: and oil of turpentine, which is a lighter, and more ſubtile liquor than water, will not, tho' poured on cold, grow ſenſibly hot with it. *Helmont* indeed, and his followers, have attempted to derive this heat, from the conflict of ſome alkalizate and acid ſalts of the quick-lime, which are diſſolved; and ſo ſet at liberty to fight with one another, by the water that ſlakes it. But tho' we have ſome manifeſt marks of an alkalizate ſalt in lime, yet that it contains, alſo, an acid ſalt, has not been proved; and if the heat be a ſufficient reaſon to prove a latent acid ſalt in lime, why may we not infer, that the like ſalt lies concealed in other bodies, which the chymiſts take to be of the pureſt ſort of alkalies? For I have purpoſely tried, that, by putting a conſiderable quantity of dry ſalt of tartar in the palm of my hand, and wetting it well with cold water, there has been a very ſenſible heat produced in the mixture: and when I have made the trial, with a larger quantity of ſalt and water, in a vial, the heat proved very intenſe, and continued to be ſenſible for a long time after. *Various mechanical ways of producing heat.*

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2. This experiment ſeems to ſhew, that the heat proceeds from the empyreuma, or impreſſion left by the violent fire, that reduced the ſtone to lime. But if by empyreuma, we mean a bare impreſſion made by the fire, 'twill be difficult to ſhew wherein it conſiſts, and how it operates in this caſe. The effect may be, alſo, aſcribed to ſwarms of fiery particles, adhering to the ſubſtance of the lime, and ſet at liberty to fly away, by the liquor; as may be conjectured from the ſlaking of lime, left, for ſome time, in the air, whereby the atoms of fire have an opportunity to fly gradually away. And, doubtleſs, we may admit the co-operation of a ſubſtantial effluvium of the fire, in accounting for the phenomenon. But it is not eaſy to apprehend, that ſuch light and minute bodies ſhould be ſo long detained, as muſt by this hypotheſis be allowed, in quick-lime; eſpecially ſince no great heat enſues the pouring of water upon minium, or *Crocus Martis per ſe*, tho' they have been calcined by a violent fire, the effluvia whereof ſeem to adhere to them, by the increaſe of weight, that lead and iron manifeſtly receive from the operation of it. And tho' one would think, that the fiery atoms ſhould either fly off, or be extinguiſhed by the water; yet I have made an experiment, in which two liquors, whereof one was natural, did, by being ſeveral times ſeparated, and re-conjoined without addition, at each conjunction produce a ſenſible heat. And an inſtance of this kind, we have in ſalt of tartar, from which, after it had been once heated by the affuſion of water, we abſtracted the liquor, without violence of fire, till the ſalt was again dry; and then putting on water a ſecond time, the ſame ſalt grew hot again in the vial, and produced the like heat a third time, and might probably have done it oftener: which ſeems, at leaſt, to argue, that the great violence of fire is not neceſſary to impreſs what paſſes for an empyreuma, upon all the calcined bodies, which will grow hot with water. Perhaps, alſo, the heat may much depend upon the particular diſpoſition of the calcined bodies, which, being deprived of its former moiſture, and made more porous by the fire, acquires, by means of thoſe igneous effluvia, ſuch a texture, that the water, impelled by its own weight, and the preſſure of the atmoſphere, is able to get into a multitude of its interſtices at once, ſuddenly diſſolve the alkalizate ſalts it every where meets with, and briſkly disjoin the earthy and ſolid particles, that were blended with them; which being exceeding numerous, tho' each of them perhaps be very minute, and moves but a very little way, yet their multitude makes the confuſed agitation of the whole aggregate, and of the particles of the water and ſalt vehement enough to produce a ſenſible heat; eſpecially, if we admit ſuch a change in the pores, as greatly increaſes this agitation, by the entrance and action of a ſubtile etherial matter, from which, alone, M. *Des-Cartes* attempts to derive the heat produced by lime and water, as well as that of metals diſſolved in corroſive liquors. But in our phenomena, there ſeems, at leaſt, to concur a peculiar

culiar diſpoſition of the body, wherein heat is produced, to retain many fiery effluvia, and to be, by their adheſion, or ſome other operation of the fire, reduced to ſuch a texture of its component particles, as fits it to have them eaſily penetrated, and greatly diſſipated by water. And this conjecture ſeems favoured by various phenomena. It may be obſerved, that both the diſſolved ſalt of tartar, lately mentioned, and the artificial liquor, which grows hot with the natural one, re-acquires that diſpoſition to heat, upon a bare condenſation, or cloſer texture of the parts, from the exhalation of the ſuperfluous liquors, wherein they were before diſperſed: the heat, which brought them to this texture, having been ſo gentle, that it is no ways likely, the fiery exhalations could, themſelves, produce ſuch an one; or at leaſt, that they ſhould adhere in numbers ſufficient to that end, unleſs the texture of the ſalt, or other body, peculiarly diſpoſed it to detain them; ſince I have found by trial, that ſal-armoniac, diſſolved in water, tho' boiled up with a briſker fire, to a dry ſalt, would not, upon its being again diſſolved in water, produce any heat, but a very conſiderable degree of cold. And tho' a great likeneſs might be expected between the particles of fire adhering to quick-lime, and thoſe of highly rectified ſpirit of wine; yet I have not found, that the affuſion of that ſpirit upon quick-lime produced any ſenſible heat, or viſible diſſolution of the lime, tho' it ſeemed to be greedily ſuck'd in, as common water would have done. And I farther tried, that if cold water was poured on this lime, ſo drenched, there enſued no manifeſt heat: nor did the lump appear ſwelled, or broken, till ſome hours after; which ſeems to argue, that the texture of the lime admitted the particles of the ſpirit of wine into ſome of its pores, which were either larger, or more fit, without admitting it into the moſt numerous, whereinto the liquor muſt be received, to be able ſuddenly to diſſipate the corpuſcles of lime into their minuter particles. I alſo made an experiment, which ſeems to favour our conjecture, by ſhewing how much the diſpoſition of lime to grow hot may depend upon a ſuitable texture. Upon quick-lime placed in a retort, we put as much ſpirit of wine, as would ſwim pretty high above it; when, diſtilling with a gentle fire, we drew off ſome ſpirit much ſtronger than that which had been put on; and then the phlegm following it, the fire was increaſed, which brought over a large quantity of weak liquor; by which, one would have thought, that the quick-lime had been ſlaked; but the remaining matter being taken out of the retort, and ſuffered to cool, it appeared to have a fiery diſpoſition, which it had not before. For if any lump of it, as big as a nutmeg, was caſt into water, it would hiſs like a coal of fire plunged into the liquor, which was thereby ſoon ſenſibly heated. Nay, having kept ſeveral lumps of this prepared calx well ſecured from the air, for many weeks, to try whether it would retain this property, I found it operate after the ſame manner, but more powerfully. For ſometimes it would, upon its coming

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PHYSICS. into the water, make ſuch a briſk noiſe, as might almoſt paſs for exploſion.

3. Theſe phenomena ſeem to ſhew, that the diſpoſition, which lime has to grow hot with water, greatly depends on ſome peculiar texture; ſince the aqueous parts, which, one would think capable of quenching moſt of the fiery atoms ſuppoſed to adhere to quick-lime, did not near ſo much weaken the diſpoſition of it to heat, as the acceſs of the ſpirituous corpuſcles, and their contexture with thoſe of the lime, increaſed it. And that ſuch an aſſociation might happen, ſeems the more probable, becauſe much of the diſtilled liquor was as phlegmy, as if it had been robbed of its more active parts; and becauſe I have ſometimes had ſpirit of wine come over with quick-lime, not in unobſerv'd ſteams, but white fumes. We may add, beſides that the taſte, and perhaps ſcent of the ſpirit of wine, is often manifeſtly changed by a well-regulated diſtillation from quick-lime; I have ſometimes found that liquor to give the lime a kind of alkalizate penetrancy of taſte, or fierineſs, which was very briſk and remarkable: tho' I have found quick-lime to differ greatly, not only with the degree of its calcination and freſhneſs, but alſo according to the various nature of the ſtones, and other bodies calcined to make it.

4. To come to the production of heat, wherein there appears nothing on the part of the agent or patient, but motion, and its natural effects. When a ſmith briſkly hammers a ſmall piece of iron, the metal thereby becomes exceeding hot; yet there appears nothing to make it ſo, except the forcible motion of the hammer, impreſſing a vehement, and variouſly determined agitation on the ſmall parts of the iron; which being a cold body before, grows, by that ſuperinduced commotion of its ſmall parts, *in* ſeveral ſenſes hot. Firſt, in a more looſe acceptation of the word, with regard to ſome other bodies compared with which it was cold before, then ſenſibly hot; becauſe this agitation ſurpaſſes that of the parts of our fingers. And in this inſtance, oftentimes, neither the hammer nor the anvil continues cold, after the operation; which ſhews, that the heat acquired by the forged piece of iron was not communicated by the hammer or anvil, as heat, but produced in it by a motion, great enough ſtrongly to agitate the parts of ſo ſmall a body as the piece of iron, without being able to have the like effect upon ſo much greater maſſes of metal, as the hammer and the anvil; tho' if the percuſſions were often and briſkly renewed, and the hammer were ſmall, this alſo might be heated; whence it is not neceſſary that a body ſhould be it ſelf hot, to give heat. And if a large nail be driven by a hammer into a plank of wood, it will receive ſeveral ſtrokes on its head, before it grows hot; but when it is once driven to the head, a few ſtrokes ſuffice to give it a conſiderable heat: for whilſt, at every blow of the hammer, the nail enters farther into the wood, the motion produced is chiefly progreſſive, and is of the whole nail, tending one way; but when that motion ceaſes, the impulſe given by the ſtroke, being unable either to drive the nail farther on, or break it, muſt be ſpent in making a various, vehement, and

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5. In the foregoing experiment, the brisk agitation of the parts of a heated iron was made sensible to the touch; I shall now add an attempt I made to render it discoverable to the eye it self. In order to this, I caused a bar of iron to be briskly struck upon by two or three lusty men, accustomed to the hammer, who dealing their strokes with as much force, and as little intermission as possible, soon render'd it too hot to be safely touched; and it would, probably, have fired gun-powder, if the metal I was obliged to use had been of the best sort: for it kindled the sulphur of many corns of that powder, and turn'd them blue. But, besides the effects of violent percussion, there are some obvious phenomena, which shew the producibleness of heat in cold iron, by causing an intestine commotion of its parts. We find, that if a piece of iron, of a convenient shape and bulk, be briskly filed with a large rough file, a considerable degree of heat will be quickly excited; the many prominent parts of the instrument giving a multitude of strokes to the parts of the iron, which happened to stand in their way, and thereby making them put the neighbouring parts into a brisk and confused motion, and consequently into a state of heat. It must not be here objected, that, upon this account, the file it self ought to grow as hot as the iron; since, the whole body of the file being continually moving backwards and forwards, the same parts, that touch the iron one moment, pass off the next; and, besides, have leisure to cool themselves, by communicating their agitation to the air, before they are brought to grate again upon the iron, which being held immoveable, receives a most perpetual shocks in the same place. We find also, that vehement attrition produces heat in the most solid bodies; as when the blade of a knife is strongly whetted; or a brass nail rubbed against a board. And I remember, that, driving our coach very fast, in exceeding hot weather, the attrition of the nave of the wheel against the axle-tree was so vehement, as obliged us to cool the parts with water, to stop the growing mischief. The common experiment of striking fire with a flint and steel, sufficiently declares, what heat may, in a trice, be produced in cold bodies by percussion or collision; the latter of which seems but mutual percussion.

6. For the sake of those who think the attrition of contiguous air necessary to produce manifest heat, we placed some hard black pitch in a bason, at a convenient distance under water, and cast the sun's rays on it, with a burning-glass, in such a manner, that, notwithstanding the refraction they suffered in passing thro' the water, the focus falling upon the pitch, would produce sometimes bubbles, sometimes smoke, and quickly communicate a degree of heat able to melt it, if not also to make it boil.

7. We have shewn that a considerable degree of cold is produced by the dissolution of sal-armoniac in common water; yet the texture of it may,

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PHYSICS. may, by an addition, be ſo alter'd, that a great degree of heat will ariſe upon diſſolving it therein. We ſlaked quick-lime in common cold water, that all the fiery, or other particles of it, to which its power of heating that liquor is aſcribed, might be extracted and imbibed, and ſo the remaining calx be freed from them; on this calx we often poured freſh water, that all adhering reliques of ſalt might be waſhed off. Then the dulcified powder, being again well dried, was mixed with an equal weight of powdered ſal-armoniac; and having, in a ſtrong fire, melted the maſs, the mixture was poured out; and being afterwards beaten to powder, having allowed it a competent time to grow cold, we put two or three ounces of it into a wide-mouth'd glaſs; and pouring water upon it, within about a minute the mixture grew warm, and quickly attained ſo intenſe a heat, that I could not hold the glaſs in my hand. And tho' this heat did not laſt long at the ſame height, it continued to be very ſenſible for a conſiderable time. And to confirm this experiment by a notable variation; we took, finely powdered, ſal-armoniac, and filings of ſteel; and when they were very well mixed, we cauſed them to be gradually ſublimed in a glaſs-veſſel; giving a ſmart fire towards the latter end. By this operation, ſo little of the mixture aſcended, that far the greateſt part of the ſal-armoniac ſtaid at the bottom with the metal; then taking out the *Caput mortuum*, I gave it time to cool thoroughly, but in a glaſs well ſtopp'd, that it might not imbibe the moiſture of the air: and laſtly, tho' both theſe bodies were actually cold, and ſo might be thought likely to increaſe, and not check the coldneſs uſually produc'd in water by that ſalt; yet putting the mixture into common water, there enſued an intenſe degree of heat. And having ſublimed the foreſaid ſalt, in diſtinct veſſels, with the filings of ſteel, and with filings of copper, and kept one of their remainders after diſtillation, for ſeveral months; we, at length, took it out of the veſſel, which had been carefully ſtopp'd, and found that the diſpoſition to give cold water a great degree of heat was ſtill preſerved in it.

8. If experiments were made after the ſame manner, with ſal-armoniac, and other mineral bodies, beſides iron, and copper, it is probable, that ſome of the phenomena thence ariſing, would confirm what we have ſaid of the intereſt of texture, and ſome few other mechanical properties in the production of heat and cold. For, three ounces of antimony, and an equal weight of ſal-armoniac, being well powdered, mixed, and, by degrees of fire, ſublimed in a glaſs-veſſel, we obtained three different ſubſtances, which we cauſed to be ſeparately powdered as ſoon as taken out of the ſubliming glaſs, leſt the air ſhould make any change in them; and having before ſet the ball of a good ſeal'd weather-glaſs, for a time, into water, that the ſpirit of wine might be brought to the temper of the external liquor, we put in two ounces of the powdered *Caput mortuum*, which ſeeming to be little other than antimony, ſcarce ſenſibly raiſed the ſpirit of wine in the thermometer.

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phureous flowers of the antimony, with a mixture of the more volatile parts of the ſal-armoniac. And this ſubſtance made the tinged ſpirit in the thermometer deſcend, very ſlowly, about a quarter of an inch; but when the inſtrument was put into freſh water of the ſame temper, and we had added ſome of the powder of the lower ſort of ſublimate, which was dark-coloured; tho' both the antimony, and ſal-armoniac it conſiſted of, had been long expoſed to the action of a ſubliming heat, yet the water was thereby ſoon cooled, ſo that the ſpirit of wine in the weather-glaſs haſtily deſcended, and continued to ſink, till it had fallen near three inches. We made a like experiment by ſubliming minium and ſal-armoniac, each three ounces; and found, that tho' in the *Caput mortuum*, the ſalt had notably wrought upon the calx of lead, and was in part aſſociated with it; yet a convenient quantity of this powder'd mixture being put into water, wherein the former weather-glaſs had been kept a while, the ſpirit of wine was not manifeſtly either raiſed or depreſs'd. And when, in another glaſs, we proſecuted the trial with the ſal-armoniac, which had been ſublimed from the minium, it did, indeed, make the ſpirit of wine deſcend; but ſcarce a quarter ſo much as it had been made to fall by the former ſublimate of ſal-armoniac and antimony.

Heat produced by mixing the ſame body, with others of ſeveral kinds.

9. The heat ariſing in the diſſolution of metals, is often aſcribed to a ſuppoſed antipathy, occaſioning a conflict, or hoſtility, between the contending bodies; and particularly between the acid ſalt of the one, and the alkalizate ſalt of the other. It will, therefore, be proper to offer ſome inſtances of the production of heat, by the operation of one agent, oil of vitriol; whence we may conſider, whether it be likely, that this ſingle agent ſhould, upon account of antipathy, or that of its being an acid, produce an intenſe heat in many bodies of very different natures. Take ſome ounces of ſtrong oil of vitriol, and ſhaking it with three or four times its weight of common water, tho' both the liquors were cold, when put together, yet their mixture will immediately grow intenſely hot, and continue conſiderably ſo for ſome time. In this caſe, it cannot be pretended, that the heat ariſes from the conflict of the acid and alkalizate ſalts, abounding in the two liquors; ſince the common water is ſuppoſed an elementary body, free from all ſalts; at leaſt, being an inſipid liquor, it can ſcarce be thought to have alkali enough, to produce ſo intenſe a heat, by its reaction. That the heat ariſing upon ſuch a mixture will be very great, when the quantities of the united liquors are large, may be eaſily concluded from hence, that I found no more than two ounces of oil of vitriol, being poured into four ounces of diſtilled rain-water, made, and kept it manifeſtly warm for above an hour; ſo that, during no ſmall part of that time, it was painful to handle it.

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PHYSICS. It ſeems extravagant to talk of heating cold liquors with ice; but I have eaſily done it, by taking out of a baſon of cold water, wherein ſeveral fragments of ice were ſwimming, one piece or two, which I perceived were well drenched with the liquor, and ſuddenly immerſing them into a wide-mouth'd glaſs, of ſtrong oil of vitriol: for the menſtruum, preſently mixing with the water which adhered to the ice, produced in it a briſk heat, ſometimes with a manifeſt ſmoke; and that ſuddenly diſſolving the contiguous parts of ice, and thoſe the next, the whole ice was ſoon reduced to water; and the corroſive menſtruum being, by two or three ſhakes, well diſperſed thro' it, the whole mixture would immediately grow ſo hot, that ſometimes the containing vial could not be endured in one's hand.

Notwithſtanding the vaſt difference between common water, and highly rectified ſpirit of wine; I found that oil of vitriol, mixed with the latter, would as well grow hot, as with common water. Nor does *this* experiment always require great quantities of liquor: for when I took but one ounce of ſtrong oil of vitriol, tho' I put to it leſs than half an ounce of excellent ſpirit of wine, yet the two being lightly ſhaken together, immediately conceived ſo briſk a heat, that they almoſt filled the vial with fumes; and made it ſo hot, that I had like to have burnt my fingers with it, before I could lay it aſide. I made the like experiment with the ſame corroſive menſtruum and common *Aquâ vitæ*; by the mixture whereof, a heat was produced in the vial, which I could not well endure. The like ſucceſs I had when oil of vitriol was mixed with common brandy; only here the heat produced, ſeemed not ſo intenſe, as in the former trial; which alſo did not afford ſo fierce a heat, as that made with rectified ſpirit of wine.

Thoſe chymiſts who conceive, that all the heat of bodies, upon their being mixed, proceeds from their antipathy or hoſtility, will hardly expect, that the parts of the ſame body ſhould, without conflict, grow very hot together. Yet having put two ounces of colcothar, calcin'd almoſt black, into a retort, we poured upon it two ounces of ſtrong oil of *Engliſh* vitriol, and found, after about a minute, they began to grow ſo hot, that I could not endure to hold my hand at the bottom of the containing veſſel; and this continued ſenſible on the outſide, for between twenty and thirty minutes.

I have not obſerved any liquor, with which oil of vitriol will grow more hot, than with common oil of turpentine. Cauſing ſeveral ounces of each to be well ſhaken together in a ſtrong veſſel, faſtened to the end of a pole, to prevent miſchief; the ebullition was ſurprizingly great and fierce. This calls to mind a pleaſant adventure afforded by theſe liquors, of each of which, having, for the production of heat, and other purpoſes, cauſed a large bottle full to be put up, with other things, into a box, and ſent down into the country, with a charge, that great care ſhould be had of the glaſſes; the waggon in which

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theſe glaſſes were both broken; and the liquors mixing in the box, made ſuch a noiſe, and ſtink, and ſent out ſuch quantities of ſmoke by the vents, which the fumes had opened, that the paſſengers, with great out-cries, haſtily threw themſelves out of the waggon, for fear of being burnt in it.

But tho' Petroleum, eſpecially when rectified, be a moſt ſubtile liquor, and the lighteſt I have had occaſion to try; yet to ſhew how much the heat of liquors may depend upon their texture, having gradually mixed one ounce of rectified petroleum with an equal weight of ſtrong oil of vitriol; the former ſeemed to work upon the ſurface of the latter, almoſt like a menſtruum upon a metal; innumerable ſmall bubbles continually aſcending, for a while, into the *Oleum Petræ*, which had its colour manifeſtly alter'd, and deepened by the operation of the ſpirituous parts. But by all the action and re-action of theſe liquors, there was produced no ſuch ſmoking and boiling, or intenſe heat, as if oil of turpentine had been employed; the change produced as to qualities, being but a kind of warmneſs, diſcoverable by the touch. Almoſt the like ſucceſs we had in the conjunction of petroleum and ſpirit of nitre.

It were eaſy to multiply inſtances of heat producible by oil of vitriol upon ſolid bodies, eſpecially upon minerals. In the uſual preparation of *Vitriolum Martis*, there is a great effervescence excited upon the affuſion of the oil of vitriol upon the filings of ſteel, eſpecially if they be well drenched in common water. And it can ſcarce be doubted, that ſince oil of vitriol will diſſolve a great many both calcined and teſtaceous bodies, as I have tryed with lime, oyſter-ſhells, *&c.* ſo it will, during the diſſolution, grow ſenſibly, if not intenſely hot with them; as I found it to do both with thoſe juſt mentioned, chalk, *Lapis calaminaris*, *&c.* with the laſt of which, if the liquor be ſtrong, it will become exceeding hot.

Let us, therefore, proceed to its operation upon vegetables, which corroſive menſtruums have ſcarce been thought fit to diſſolve and grow hot with. To omit cherries, and ſeveral other fruits, abounding in watry juices, with which, perhaps, on that account, oil of vitriol will grow hot; having mixed a quantity of this liquor with raiſins of the ſun, beaten in a mortar, the raiſins grew ſo hot, that the glaſs, which contained them, almoſt burnt my hand. This kind of heat may alſo be produced by the mixture of oil of vitriol with many other vegetable ſubſtances; but as far as I have obſerved, ſcarce ſo eminently with any dry body, as with crumbs of bread; with a little of which, and ſtrong oil of vitriol, we have ſometimes produced a ſurprizing degree of heat. It is as little obſerved, that corroſive menſtruums will work on the ſoft parts of dead animals, as on thoſe of vegetables; yet I have, more than once, produced a notable heat, by mixing oil of vitriol with minced fleſh, whether roaſted or raw.

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PHYSICS. Tho' common ſea-ſalt uſually imparts ſome degree of coldneſs to common water, during its diſſolution; yet ſome trials have informed me, that, if thrown into a competent quantity of oil of vitriol, a heat will, for the moſt part, enſue; tho' it yet did not appear to ſucceed ſo regularly, as in moſt of the foregoing experiments. But that heat ſhould be uſually produced, by oil of vitriol and ſalt, ſeems the more remarkable, becauſe common ſalt is one principal ingredient of common factitious ſal-armoniac. And I have been informed, that in the academy at *Florence*, oil of vitriol has been obſerved not to grow hot, but cold, by being put upon ſal-armoniac: and ſomething like this I took notice of in rectified ſpirit of ſulphur *per Campanam*; but found the effect much more conſiderable, when, according to the *Florentine* experiment, I made the trial with oil of vitriol.

Other ways of producing heat, in ſolids, powders, metals, &c.

10. To proceed to ſome other experiments, wherein oil of *vitriol is* not concerned. We took a large lump of common ſulphur, and having chafed it well, found it thereby grow ſenſibly warm; and that there was an inteſtine agitation made by this attrition, appear'd not only from the heat, whoſe nature conſiſts in motion, and the antecedent preſſure, which was fit to put the parts into a diſorderly vibration, but alſo by the ſulphureous ſteams, which were eaſily ſmelt by holding the ſulphur to the noſe. This experiment, tho' it ſeems trivial in itſelf, may be worth the conſideration of thoſe chymiſts, who derive all the fire and heat we meet with, in ſublunary bodies, from ſulphur. For, in our caſe, a maſs of ſulphur, before its parts were put into a new and briſk motion, was ſenſibly cold; and as ſoon as its parts were put into a greater agitation than thoſe of a man's fingers, grew ſenſibly hot; which argues, that it was not by its bare preſence, that the ſulphur communicated any heat to the hand; and alſo, that when briſkly moved, it impreſs'd that quality, it did no more than another ſolid body, tho' incombuſtible, as common glaſs, would have done, if its parts had been likewiſe put into an agitation ſurpaſſing that of the organs of feeling: ſo that in our experiment ſulphur itſelf was beholden, for its actual heat, to local motion, produced in its parts by external agents.

We thought proper to try, whether, when ſal-armoniac, which greatly cools water, and quick-lime, which is known to heat it, were, by the fire, exquiſitely united, the mixture would impart to the liquor any intenſe degree of either quality. To this end, we took equal parts of ſal-armoniac, and quick-lime, and fluxed them together, and putting an ounce of the powdered mixture into a vial, with a convenient quantity of cold water, I found the diſſolved maſs, in about a minute, ſtrike ſo great a heat thro' the glaſs upon my hand, that I was glad to remove it haſtily, for fear of being ſcorched.

We have given ſeveral inſtances of the heat of mixtures, wherein both the ingredients were fluid, or at leaſt, one of them; but ſometimes heat may be produced, alſo, by the mixture of two powders: for

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mixed with powdered antimony, the mixture, after it has, for a competent time, ſtood in the air, would ſometimes grow manifeſtly hot, and now and then to that degree, as to ſend out vaſt fetid fumes, almoſt as if it would take fire.

There is another experiment, made by the help of antimony, and a pulverized body, wherein the mixture, after it had been expoſed to the air for ſeveral hours, viſibly afforded us mineral fumes. But in this caſe, perhaps, there happens unobſervedly an aqueous moiſture, which, I ſuſpected, may be attracted from the air; ſince the mixture of the antimony and the ſublimate, deſigned for the butter of antimony, is preſcribed to be placed in cellars; where we find that ſublimate, at leaſt the ſaline part of it, is diſſolved *per diliquium*.

I have given ſome inſtances of the heat produced by water in bodies, which are readily diſſolv'd in it, as ſalt of tartar, and quick-lime; but one would not expect that mere water ſhould produce heat in ſolid bodies, which are generally granted to be inſoluble in it; yet trial has aſſured me, that this may be done in flower, or fine powder of ſulphur, and filings of ſteel or iron. For when, in ſummer-time, I cauſed a pound of each to be firſt mixed and thoroughly drenched with common water, wherein they were very well ſtirred, the mixture would, in a ſhort time, grow ſo hot, that the containing veſſel could not be ſuffered in the hand: a ſtrong ſulphureous ſmell, and a thick ſmoke were, alſo, produced thereby.

In the inſtances which chymiſtry uſually affords us of the heat produced by the action of menſtruums upon other bodies, ſome humid liquor is concern'd; and there are many who deny, that quick-ſilver, which is indeed a fluid, tho' not moiſt with regard to us, will produce heat by its immediate action on any other body, and particularly on gold: but ſeveral trials have aſſured me, that a particular mercury may, by preparation, be enabled ſuddenly to inſinuate itſelf into the body of gold, whether calcined, or crude, and become manifeſtly hot with it, in leſs than two or three minutes. And ſince we know that ſome natural ſalts, eſpecially ſalt-petre, produce a coldneſs in the water wherein they are diſſolved, I thought it might, alſo, help to diſcover the ſtructure of metals, and the ſalts that corrode them, if ſolutions were made of ſome bodies, which conſiſt of metalline and ſaline parts; and ſo abound with the latter, that the whole concrete is on their account diſſoluble in common water: of this ſort of experiments, I ſhall here only take notice of one, that we made upon quick-ſilver, which is eſteemed the coldeſt of metals. From this, having diſtilled four times its weight of oil of vitriol, and thereby reduced it to a powder, which, on account of the adhering ſalts of the menſtruum, was white and glittering; we put this powder into a wide-mouth'd glaſs of water, wherein a ſealed weather-glaſs had before been left,

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PHYSICS. when, it began manifeſtly to heat it; as appeared by the quick and conſiderable aſcent of the tinged ſpirit, that continued to riſe upon putting in more of the magiſtery. This event is the more remarkable, becauſe *Helmont* obſerves, that the ſalt adhering to the mercury, corroded by oil of vitriol, becomes, if it be waſhed off, and coagulated, a kind of alum; and ſtill more, becauſe having, after the ſame manner, and with the ſame weather-glaſs, made an experiment with common water, and the powder of *Vitriolum Martis*, prepared with oil of vitriol, and the filings of ſteel; the tinged ſpirit was not at all impell'd up as before, but rather, after a while, began to ſubſide, and fell, tho' very ſlowly, about a quarter of an inch. The like experiment being tried with powdered ſublimate in common water, the liquor in the thermometer was ſcarce at all, ſenſibly, either raiſed, or depreſs'd; which argued the alteratiou, as to heat or cold, to have been either none, or very inconſiderable.

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MEMOIRS

FOR AN

EXPERIMENTAL HISTORY

OF

COLD

Heads for an experimental history of cold.

1. *EXperiments with bodies capable of freezing others.*
2. *Experiments and observations upon bodies disposed to be frozen.*
3. *Experiments upon bodies indisposed to be frozen.*
4. *Experiments and observations about the degrees of cold in several bodies.*
5. *Experiments of the tendency of cold, upwards or downwards.*
6. *Experiments and observations of the preservation and destruction of bodies by cold.*
7. *Experiments of the expansion of water and aqueous liquors by freezing.*
8. *Experiments of the contraction of liquors by cold.*
9. *Experiments in consort, relating to the bubbles, from which the levity of ice is supposed to proceed.*
10. *Experiments about the measure of the expansion and contraction of liquors by cold.*
11. *Experiments of the expansive force of freezing water.*
12. *Experiments about a way of estimating the expansive force of congelation, and of highly compressing air without engines.*

13. *Ex-*

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13 *Experiments and obſervations to determine the ſphere of activity of cold.*
14. *Experiments about different mediums, thro' which cold may be diffuſed.*
15. *Experiments and obſervations upon ice.*
16. *Experiments and obſervations of the duration of ice and ſnow, and the deſtruction of them by the air, and ſeveral liquors.*
17. *Conſiderations and experiments upon the* Primum Frigidum.
18. *Experiments and obſervations as to the coldneſs and temperature of the air.*
19. *The ſtrange effects of cold.*
20. *Experiments upon the weight of bodies frozen and unfrozen,*
21. *Promiſcuous experiments and obſervations upon cold.*

I.

Our ſenſes and the common thermometers may miſinform us of cold.

TO examine ſollicitouſly into the way of eſtimating the coldneſs of bodies, will, to many, appear a needleſs taſk; the organs of feeling, being generally thought the proper judges hereof: and, accordingly, both the ancient and modern philoſophers ſeem to have taken up with this bare information of the matter. But as too much care cannot be ſhewn in examining the criteria of things, we ſhall take a cloſer view of this ſubject. For tho' cold, in its obvious idea, has relation to the ſenſe of feeling, yet it remarkably affects many other bodies beſides ours, and in ſome of them produces more ſenſible and leſs uncertain changes; and, therefore, in eſtimating the degrees of this quality, we ought to obſerve its effects in thoſe bodies: for our ſenſes, alone, or aſſiſted by the common weather-glaſſes, are not to be relied on in this particular. To render the aſſertion credible, let it be conſider'd, that the reaſon why a body is uſually ſaid to be cold is, that we feel its particles leſs agitated than thoſe of our fingers, or other organs of touch; whence, as the temper of that organ changes, the object may ſeem more or leſs cold, while it remains uniformly the ſame. Thus we find in bathing, the milder degree of heat paſs'd thro' to prepare us for the greater, ſeems very hot, when we immediately change it for the open air; and even chilling cold, upon returning back from the ſweating-room. But beſides theſe obvious changes, there are other ſecret ones, in the diſpoſition of our organs, that require a philoſophical head to obſerve them. For taking our temper to be the ſame, when no manifeſt cauſe of its alteration appears, we frequently impute to objects what reſides in our ſelves; when, if the change be wrought by unſuſpected agents, or by inſenſible degrees, we are apt to overlook it. Many cellars are, perhaps

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haps, no colder in the ſummer, than in winter, or the ſpring, tho' they will feel cold to us, who deſcend into them, with bodies heated by the ſummer's ſun, and accuſtom'd to a warmer air. Nay, cold ſo greatly depends upon the agitation of the parts of the object, that even when the organ ſeems unalter'd, it may refer a degree of coldneſs thereto, which that really hath not. Thus air, blown out of a pair of bellows upon an exact thermometer, appears not to acquire any coldneſs, by being turn'd into wind, tho' any part of our bodies wou'd judge it cold; the reaſon whereof is, that tho' the organ remains unchanged, the wind, by its motion, drives away the air contiguous to the ſkin, together with the warm effluvia of the body which temper'd its coldneſs, and alſo penetrates deeper into the pores of the ſkin, where it is leſs agitated than the internal parts, and conſequently feels colder. There may likewiſe, at particular times, be certain exhalations in the air which have a ſecret power of chilling the blood and ſpirits of human bodies; for opium, externally applied, ſtrikes a coldneſs into the body by the ſubtile effluvia it ſends thro' the pores of the ſkin. Perhaps, alſo, that coldneſs is aſcribed to external cauſes, which ſome cold vapour, or very ſlight diſeaſe produces in us, bearing reſemblance to what the phyſicians term horrors and rigors, at the beginning of fevers, *&c.* or occaſioning that ſtrange, univerſal coldneſs of the external parts, which is a common ſymptom in hyſterical caſes. Again, bodies may often ſeem colder to us than we ſhall find them by the thermometer; becauſe our organs are more affected by the denſity and inſinuation of particles, than the inſtrument. This I have frequently experienced in very nice thermometers; for water has appeared ſufficiently cold to our touch, when the glaſs ſhew'd it to be no colder than the air. PHYSICS.

1. *June* 26. between two and four of the clock in the afternoon, the weather being ſeaſonable, I plunged the open ſtem of the ſmall glaſs egg C D B A, into water, whence it received a cylinder of that fluid, about half an inch in length, which ſubſided, when the glaſs was erected perpendicularly, by its own weight, or by means of the temper of the included air, to the lower part of the pipe next the egg; then immerſing the egg in a baſon of cold water, the ſmall cylinder that lay between the external and internal air, preſently aſcended from the lower part of the pipe to the middle thereof; and being taken out of the water, and placed again in the air, the cylinder would again ſubſide, whether the glaſs were ſuſtained by my fingers, or ſuffered to reſt alone. This experiment I ſeveral times repeated: and if inſtead of water, I made uſe of quick-ſilver, to half cover the egg, the cylinder of water would preſently mount to the top of the pipe, and fall back again when the glaſs was taken out. Having, alſo, placed the veſſel of quick-ſilver and baſon of water near each other, and ſuffering the pendulous cylinder to aſcend to its utmoſt height in the latter, I nimbly took it out, and plunged it into the former, where the

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PHYSICS. the cylinder roſe much higher; and the contrary happened upon removing the egg out of the quick-ſilver into the water; tho' the deſcent was neither ſo ſudden nor great, as if the glaſs had been removed from the mercury into the air. At another time, when the weather was windy and rainy, the pendulous cylinder in the pipe ſunk upon the immerſion of the glaſs into water, both in the morning and afternoon; but not ſo much nor ſuddenly as in the preceding mornings.

2. *June* 27, in the morning, a ſmall cylinder of water, ſuſpended in the above-mention'd glaſs, immerſed in water, immediately ſubſided to a conſiderable depth; but when plunged in quick-ſilver, preſently aſcended. Both parts of this experiment were often repeated. The reaſon of the phenomenon we ſuſpected to be the warmth that the quick-ſilver had acquired by remaining all night in a chamber; whilſt the water was freſh, and felt ſomewhat colder; and accordingly, in the afternoon, the water having alſo ſtood in the chamber, both that and the mercury would immediately, upon immerſion, impel the pendulous water up into the pipe.

3. In the beginning of *January*, while the weather was froſty, we took up a few drops of water, as above, from a parcel ſet by, for a conſiderable time, to acquire the temperature of the air; and ſuffering the cylinder to remain long ſuſpended, that the internal air might have the ſame temper as the external, we immerſed the egg into a ſhallow veſſel of the ſame water; whereby the ſmall pendulous cylinder was ſuddenly impell'd upwards to the height of half an inch; when, the ball of the thermometer being taken out of the water into the air, it again ſlowly ſubſided. This was ſeveral times repeated, at intervals, in a cloſe room, and with the ſame ſucceſs, except that in the two laſt trials, when the thermometer was taken out of ſhallow water, and plunged deep into an adjoining parcel, the pendulous cylinder roſe to twice the height it had done in the former; and when taken from this deep glaſs, and expoſed to the air, it therein again deſcended to its low ſtation.

I lay no great ſtreſs, indeed, upon theſe experiments, yet ſmall-ſeal'd thermometers have given me cauſe to ſuſpect that we receive different informations, as to the degrees of heat and cold in the air, by our organs of touch, and proper inſtruments. We may alſo allow, that not only water, but moiſt vapours in the air, will cauſe us to think it colder than the thermometer ſhews it to be. I, my ſelf, have ſometimes felt the weather more or leſs cold than the preceeding, when the contrary has appeared in that inſtrument; tho' no obvious circumſtance, or alteration in my body was concerned. Nor cou'd this be the effect of any peculiarity in my conſtitution; for, upon inquiry, others have agreed with me in the reality of the fact. It might, therefore, be proper to obſerve the ſenſe expreſſed by birds and other animals (whoſe diet is more ſimple and regular, and whoſe perceptions are commonly more delicate and leſs diverted than ours) of

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of the degrees of cold; and particularly to examine the coldneſs of the air, and of other bodies, as well by experiments and inſtruments, as by the touch. *Martinius*, in his *Atlas Chinenſis*, tells us "that the "cold is greater in a certain part of *China*, than its latitude, of forty "two degrees, would induce one to expect; for all the rivers, "ſays he," "are here often frozen for four months together, ſo as to bear horſes, "carriages, *&c.* during which time, there's no ſailing for ſhips; and "this hard weather beginning about the middle of *September*, the ice "is not thaw'd before *March*; for tho' the water be commonly froze "thus hard in one day's time, it requires a great many to thaw the "ice." He adds, "'tis ſurprizing, the *Europeans* ſhould remain un-"affected by this cold, and ſlight it as unable to produce ice in their "quarter of the world; for which reaſon we muſt ſuppoſe ſubterraneous "effluvia to be the cauſe hereof." The common thermometer is, indeed, an uſeful invention, and the informations it gives us are, in many caſes, preferable to thoſe of our ſenſes; but we greatly over-value it, by ſuppoſing it an exact and perfect meaſure of heat and cold. Its contrivance is liable to ſeveral exceptions; whence it becomes unapplicable in ſome caſes, and improper in others. Beſides, part of the liquor being here contiguous to the external air, 'tis apt to riſe and fall, not only as heat or cold affects the included air, but according to the different weight of the atmoſphere; as both reaſon and experience aſſure us. Thus an ingenious phyſician found at the bottom of a very deep mine, that the water in a common thermometer, roſe three inches higher than at the mouth thereof; which, notwithſtanding the uſual warmth of ſuch deep places, was owing to the additional preſſure of a column of the air, equal to the depth of the mine below the earth's ſurface. I have, alſo, frequently obſerved great variations to happen in the mercurial barometer upon conſiderable rains, fogs, or other remarkable and ſudden alterations in the air; and the ſame being likely to happen in the common thermometers, 'tis eaſy to miſtake the riſe or fall of the fluid they contain, for the effect of a greater or leſs degree of cold.

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4. Two thermometers of a large diviſion, and furniſhed with ſpirit of wine, one of them ſealed, the air being ſhut up in its lower part, the other open, as uſual, at top, being placed in a cloſe room, the fluid in the ſealed glaſs, regularly deſcended in cold weather, and aſcended in warm; and that with a ſmall hole at the top, roſe and fell with the other, whilſt the atmoſphere continued of the ſame weight; but when that became greater, the liquor here ſtop'd ſhort of the height whereto it would, otherwiſe, have mounted. On the contrary, when the atmoſphere grew lighter, the liquor roſe higher in the open glaſs, than the increaſe of heat, alone, required; ſo that by comparing theſe two thermometers together, I could, uſually, foretel the height of the mercury in the *Torricellian* tube, and contrarywiſe, from the barometer, predict the different aſcent of the liquor in them. And once particularly, upon

Fig. 3. and 4.

Fig. 5.

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PHYSICS upon a conſiderable change of weather, which occaſion'd a great fall in the barometer, I found the liquor in the open glaſs, riſen ſeventeen diviſions higher than that in the other, tho' they before ſtood nearly level; and comparing the height of each, with the mercury in the barometer, obſerved a week before, the fluid in the ſealed glaſs had in that time deſcended five diviſions, whilſt the other in the open one, had aſcended thirty one.

At another time, when the mercury ſtood higher than it had for a conſiderable while, whilſt the weather was warm and clear, and the fluid in the ſealed glaſs riſen to fifty, that in the other was ſunk to thirty two. From hence it is very poſſible, that an unregarded change in the weight of the external air, may compreſs that included in an open thermometer, more than a conſiderable degree of warmth can dilate it; and, conſequently, common thermometers, which include air in their tops, contrary to the common opinion, may riſe in warmer, and fall in colder weather.

If this wants farther confirmation, I might add, that, very lately, the mercury in the barometer, ſtanding at twenty nine inches, and the liquor in the two above-mentioned weather-glaſſes, at nearly an equal height; upon the quick-ſilver's riſing ¼ inch, the liquor in the ſealed glaſs aſcended to forty five, whilſt that in the open one, deſcended below thirty five; that, upon the mercury's riſing ¼ inch, the open glaſs ſunk twenty three diviſions, whilſt the ſealed one preſerved its ſtation; that, the ſame being riſen to thirty inches, the ſealed thermometer ſtood at forty one, and the other below nine; laſtly, that the quick-ſilver continuing at thirty one inches, but the weather become much colder, the liquor appeared to have uniformly ſubſided in both glaſſes, ſtanding in the ſealed one at thirty three, but ſunk in the open one quite below the bottom mark, which I thought impoſſible without froſt; for having before obſerved the ſealed glaſs to ſtand at thirty four, the other was no lower than forty one; whence I conjecture, that the additional weight of the atmoſphere was the cauſe of this great difference; the quick-ſilver being now riſen to twenty nine inches, and almoſt an half. To conclude, the laſt obſervations I made of this kind ſhew a greater variation in theſe glaſſes, than any hitherto mention'd; the former being that of forty five diviſions: and the latter, being made upon ſomewhat a leſs exact glaſs than the above-mention'd, including air in its lower part; when the quick-ſilver in the barometer had aſcended ¼ inch above its former ſtation, the preceding night, the tinged liquor, in the ſhank, that meaſured twenty inches, was, in no cold ſeaſon, depreſſed above an inch below the ſurface of the ſurrounding fluid of the vial wherein 'twas plunged; whilſt a bubble of the external air was ſeen to paſs thro' the liquor, and join that contain'd in the vial. Such a difference is, doubtleſs, too ſurprizingly great to be alone, attributed to the heat or coldneſs of the air.

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II.

Observations upon the defects of thermometers; and the sealed kind of that instrument considered.

We are greatly at a loss for a standard whereby to measure cold. The common instruments shew us no more than the relative coldness of the air; but leave us in the dark as to the positive degree thereof: whence we cannot communicate the idea of any such degree to another person. For, not only the several differences of this quality have no names assign'd them, but our sense of feeling, we see, cannot herein be depended on; and thermometers are such very variable things, that it seems morally impossible from them to settle such a measure of coldness as we have of time, distance, weight, &c. There are many degrees of coldness between lukewarmness and freezing cold, which we cannot express in words; and even the terms here used are very indefinite: for what to one is lukewarm, will be judg'd hot by a second, and perhaps cold by a third; and we find that different fluids, as oil, water, and wine, or even liquors of the same denomination, as different kinds of water, manifestly freeze more easily one than another. And, perhaps, the mildest degrees of cold suffice to turn some waters into ice; so that the differences of scarce any quality want names so much as those of cold.

Whoever makes many observations with a thermometer, is so confin'd to that numerical glass, that any one of those numerous accidents, whereto 'tis exposed, would, tho' he retriev'd his instrument, reduce him to find a new standard whereby to measure the varying temper of the air: not to mention how exceeding difficult it is to include any fluid body, instead of air, in one of these glasses, fit to shew the alterations in the atmosphere, without receiving impressions therefrom in its first admission. Tho' I have sometimes consider'd whether the essential oil of aniseeds might not, during a considerable part of the year, be of use in the making and judging of thermometers; for this substance having the property to remain congeal'd at all times, when the weather is moderately cold; if by being thaw'd, and plac'd round the ball of the thermometer, furnished with rectified spirit of wine, and there suffered to congeal again of it self, the height of the spirit of wine be observed, when the oil begins to curdle; this may assist towards making another thermometer like the former: for if the like spirit of wine be placed in an equal and similar glass, a few careful trials made with this oil, thaw'd and congeal'd again, might bring the second glass to a similitude with the other. And if the quantity of the spirit be known, an estimate may be easily made, by the height it reaches in the neck of the instrument, of a known capacity, to what part of its original bulk it contracts. By means of the same oil, a conjectural estimate might also be made of the difference between two thermometers unequal in magnitude. 'Tis true, there are many ob-

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PHYSICS. jections to be made about the uncertainty of this method, propoſed as a ſtandard for weather-glaſſes; yet it may be of ſome ſmall ſervice in comparing and making theſe inſtruments. Another attempt to anſwer this end is, by obſerving the coldneſs requiſite to begin the congelation of diſtill'd water: but the accuracy hereof is as queſtionable as the former; and 'twill often be found impracticable, even in the winter: 'tis alſo troubleſome, but may prove ſucceſsful, when the cold is ſufficient to freeze water.

But to leave this difficulty, which ſeems almoſt inſuperable, we may obſerve avoidable inaccuracies in meaſuring cold by thermometers. The ſtems employ'd herein are not always ſufficiently even and cylindrical; but generally wideſt near the bubble: and a proper proportion might be obſerved between the bore and the ſpherical part, which wou'd greatly increaſe the certainty and uſefulneſs of the inſtrument. Thoſe where part of the liquor is expoſed to the external air, might be much better contrived, at leaſt for particular purpoſes, than what are commonly uſed; ſome whereof I have myſelf employ'd, that were made by inſerting the end of an open cylindrical glaſs tube into a vial, and cloſing its mouth with cement, to prevent a communication between the external and internal air, except by the pipe. By this means, if you make choice of a large vial and a ſlender cylinder, the riſe and fall of the liquor employ'd, will be ſeveral times greater than in the ordinary glaſſes, where the air is confin'd in a much narrower ſpace. Theſe glaſſes not only allow of larger diviſions, and require no frames, which are conſiderations I here neglect, but are well fitted for many experiments, as we ſhall ſee hereafter on liquors and other bodies; they being eaſily applicable hereto: and thus not only the coldneſs of fluids, but of earth, ſnow, powder'd ice, *&c.* may be meaſured, by burying the vial in each reſpectively.

Fig. 6.

Again, 'tis generally concluded, that if the coldneſs of the weather cauſes the thermometer to riſe, for example, one inch to-day, and another to-morrow, the air is twice as cold on the ſecond day, as it was on the firſt; but the truth hereof ſeems very queſtionable: for tho' cold be allow'd to contract the air, yet it does not from hence follow, that a double degree of cold will cauſe a double condenſation in the air. For not only the different quantities of the included air in ſeveral inſtruments, the different capacities of the pipes, and degrees of the air's expanſion, when included, render this hypotheſis very ſuſpicious; but the condenſation of the air, and aſcent of the liquor, chiefly proceed from the preſſure of the external air; and the power required to compreſs air is, in a reciprocal proportion to the ſpace wherein it is included; ſo that, for inſtance, if the reſiſtance of a four inch cylinder of air, be, when compreſs'd into two inches, a ballance for ten pound weight; an additional force equal to the former, will force it into the ſpace of an inch; whence, the condenſation of the air in thermometers

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former degree of denſity. Nor muſt the reſiſtance of the included air be look'd upon as that of a weight, continuing always the ſame, but that of a ſpring, forcibly bent, which attempts to reſtore its ſelf in proportion as it is compreſs'd.

The particular nature of the liquors employ'd in thermometers will alſo claim our regard, till the theory of cold becomes more perfect; for tho' of two fluids, the one is more diſpoſed to freeze than the other, the latter will not therefore be leſs ſuſceptible of the lower degrees of cold than the former: the thermometer made with ſpirit of wine much ſooner receives impreſſions from a faint degree of coldneſs, than thoſe that are made with water. Moreover, we cannot always be certain, that the more ſubtile and ſpirituous liquors are leaſt ſubject to congeal or loſe their fluidity; for the chymical oil of aniſeed, a very ſubtile, ſtrong and heating liquor, is more eaſily froze by cold than common water, and will remain in that ſtate for many days after ice is thaw'd into water again. There are, alſo, other diſtill'd liquors, whoſe particles, tho' vehemently agitated, and exceſſively pungent on the tongue, and in theſe reſpects, perhaps, not inferior to *Aqua fortis*, may be congeal'd by a far leſs degree of cold than wou'd freeze the common chymical oils, or ſaline ſpirits. And till the nature and cauſes of cold be better underſtood, 'tis not abſurd to imagine, that tho' ſome bodies ſeem fitted to produce this quality indifferently in all the ſubſtances they invade; yet if the refrigeration of a body be only the leſſening of the agitation of its parts, there may be peculiar frigorific agents, beſides thoſe corpuſcles that ſeem to be the univerſal efficients of cold, for particular bodies. Thus mercury is congealed by the ſteams of lead, tho' theſe appear to have no ſuch effect upon any other fluid; and tho' ſuch a degree of cold as will freeze water or wine, will not deprive quick-ſilver of its fluidity. And by the preceding relation of *Martinius* it appears, that water itſelf, in ſome countries, may, by the nature of the ſoil, be ſo diſpoſed as to receive ſtrange impreſſions of cold in proportion to the effect, which a particular degree thereof there has upon human bodies. And opium, three or four grains whereof will deſtroy the heat of the whole maſs of blood in a man, does not, as far as I cou'd find by a good ſeal'd thermometer, ſenſibly refrigerate water; which ſeems to argue, that as different liquors have their peculiar texture, ſo certain bodies may, by the mechanical affections of their particles, be qualified to hinder the agitation of the parts of a particular liquor, into whoſe pores they inſinuate, without having the like effect in other liquors of a different texture. What confirms me the more in this conjecture is, that I know ſome liquors, which will inſtantly congeal, even highly rectified ſpirit of wine. And the ſame I have, alſo, effected in other

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PHYSICS. other fluids. 'Tis true, in theſe experiments a congelation ſeems to be produced without any great additional coldneſs; yet I may here ſay, that by adding a particular ſubſtance, that wou'd ſcarce ſenſibly refrigerate common water, I can communicate a conſiderable degree of coldneſs to a particular fluid, which, to the touch, ſeems nearly of the ſame temper with water.

The ſealed weather-glaſſes, which I firſt introduced in *England*, are, in ſeveral reſpects, preferable to the common ſort. I found, indeed, ſome difficulty in bringing it to be allow'd, that a liquor hermetically ſealed, wou'd rarify and condenſe, tho' ſome experiments aſſured me thereof; and I afterwards gain'd ſight of a ſmall thermometer brought from *Florence*, which farther convinced me of its poſſibility: but to fill the longer ſort, is a taſk exceeding nice and difficult. The preſſure of the atmoſphere, which greatly diſturbs the common kind, is prevented in theſe, which may therefore be uſed with equal ſucceſs in any place, how high or deep ſoever. Neither is the liquor they contain liable to evaporate, or to be ſplit in carrying: they may alſo be ſafely let down into the ſea, or immers'd in any kind of fluid. The liquor employ'd in them, is highly rectified ſpirit of wine, tinged of a fine red with cochineal, open'd by volatile ſpirit of urine; ſo that we thus render it very conſpicuous, ſecure it from freezing, and keep it ſuſceptible of the ſlighteſt impreſſions from without; and 'tis ſurprizing to ſee how many inches high the liquor will riſe in the cylindrical pipe of this uſeful inſtrument, by means of a ſmall degree of heat. We are the more particular upon this kind of thermometer, becauſe we ſhall hereafter make frequent mention thereof. But a philoſopher will not rely ſo much upon them, as to neglect ſearching after other more certain methods of meaſuring the degrees of cold, than either theſe or our ſenſes afford; for this inſtrument is not exempt from the imperfections formerly mention'd. And tinged ſpirit of wine, being a particular mixture, 'tis poſſible, the ſubtile effluvia of ſome bodies may get into it thro' the pores of the glaſs, which are permeable to the effluvia of the load-ſtone. To countenance this conjecture, I ſhall relate an odd phenomenon, which I obſerved ſince I began to write this hiſtory. Examining the temper of a ſtrange mixture, (to be particularly mention'd hereafter) with one of our ſealed thermometers, by burying its ball and part of the ſtem therein; whilſt to the touch it ſeem'd only lukewarm, the liquor was ſlowly impell'd to the height of nine inches in a tube, but little above a foot in length; when, the inſtruſtrument being removed from thence into a deep glaſs of cold water, out of which we took it, to make the foregoing experiments, the tinged ſpirit did not attempt to ſubſide, but continued within half an inch of the very top of the thermometer, tho' it appear'd no where diſcontinued by any bubble of air, which might have been occaſion'd by the warmth of the mixture. But what was ſtill more ſurprizing,

half an inch; nay, tho' the glaſs were let ſtand for a whole night in the window of a cloſe room, the liquor had not ſenſibly deſcended in the morning. Hence even ſeal'd thermometers, furniſh'd with highly rectified ſpirit of wine, may ſometimes be affected by peculiar agents, that appear not to be the genuine effects of heat and cold.

Orthelius tells us, that a liquor diſtill'd from the ore of biſmuth, will conſiderably ſwell in the including glaſs at the time of the full moon, and ſhrink at that of the new; but having never been able to procure this ore, I can neither confute nor confirm ſo ſtrange a phenomenon. *Caſatus*, indeed, makes mention hereof, but not from his own obſervation. This however brings to mind, that I have made a tincture of amber, with highly rectified ſpirit of wine, which did, for many months, tho' kept in a well-ſtop'd glaſs, manifeſt certain changes, ſuſpected to proceed from ſome ſecret alterations in the air, which here operated more remarkably than ever I had obſerved upon any liquors wherein ſpirit of wine abounded. And, perhaps, by careful obſervations, long continued, upon thermometers fill'd with various liquors, and kept in the ſame place, a difference wou'd appear between them, that cou'd be attributed to nothing ſo properly as the peculiar nature of the ſeveral fluids, which might be variouſly tinged by copper; as ſuppoſing *Aqua fortis*, *Aqua regia*, ſpirit of urine, ſpirit of ſal-armoniac, or oil of turpentine employ'd herein. But that ſealed thermometers, fill'd with ſpirit of wine, may be affected in a different manner from what is uſually imagin'd, appears from the bubbles, which, after ſome time from their making, have emerged therein, and poſſeſs'd the ſpace of ſeveral inches in the ſhank of the longer ſort. And if theſe bubbles be ſmall, and lurk between the ſpherical and cylindrical part of the glaſs, they eaſily paſs unheeded, and prevent the ſpirit from moving according to the changes of the weather; for ſuch a bubble is more indiſpoſed than the liquor, to riſe and fall in the ſlender tube. Hence it might be worth while to make collateral experiments and obſervations, to rectify or confirm the thermometer, in the notices it gives us of cold; and perhaps a careful enquiry might procure us ſeveral other bodies, either natural or factitious, for this purpoſe. Thus, tho' water, for inſtance, be thought the moſt apt fluid to freeze, yet we have diſtill'd a ſubſtance from benjamin, that will both congeal and thaw much more eaſily than that. Thus, alſo, I have obſerv'd a ſolution of amber-greaſe, made with ſpirit of wine, in ſulphureous or reſinous tinctures, and other chymical liquors prepared from urine, hartſhorn, *&c.* wou'd ſometimes ſhew perfectly clear, and at others, ſuffer a greater or leſs proportion of the imbibed ſubſtance to fall to the bottom, or cryſtallize, according to the alterations in the weather, as

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PHYSICS. to heat and cold. But, to return to water, 'tis obſerved that the rivers in ſome parts of *France* will ſuſtain boats heavier loaded in the winter than in the ſummer; and ſailors have inform'd me, that their ſhips draw leſs water upon the coaſts of frozen countries, than in the *Britiſh* ſeas; which ſhews water to be heavier in winter than in ſummer. The like difference is, alſo, obſervable in water at different times of the day, according as the air is then colder or warmer; for having nicely pois'd a glaſs bubble, hermetically ſealed, to float any where in water in the morning; it would about noon, when that fluid was rarified by the heat, ſink to the bottom, and at night gradually riſe again, ſo that by the next morning 'twas uſually emerged to the top; and at other intermediate times of the day, it would, frequently, continue ſwimming up and down, between the bottom and the top, without reaching to either of them. Upon the whole, as by reaſon of the various and unheeded prediſpoſitions of our bodies, the immediate informations of our ſenſes, are not always to be truſted as to the degrees of cold; ſo the common thermometers are uſeful inſtruments, and, in moſt caſes, preferable to our touch, being leſs ſubject to unregarded changes than that ſenſe; yet as theſe inſtruments are affected by the different weight of the atmoſphere, as well as by heat and cold, they may eaſily, in ſeveral caſes, give us a wrong intelligence, unleſs the preſſure of the atmoſphere be, at the ſame time, obſerved by other means. The ſealed glaſſes are far ſuperior to theſe, and, in particular, are not ſubject to the external preſſure of the air; ſo that they here deſerve to be depended on more than any other inſtrument hitherto diſcovered; yet in caſes of nicety, other methods of examining the coldneſs of bodies ſhould be uſed. And in the laſt place, we ought not to be diſcouraged from making various experiments, with relation to the meaſure of cold; tho' they ſeem contrary to the vulgar notions thereof: for our theory of that quality is very defective, and ill grounded. I ſhould never have attempted to make ſealed thermometers, if the popular notions of a *Fuga vacui* cauſing water to be ſuſpended in glaſs tubes, and of air being much eaſier condens'd by cold than any other liquor, had prevail'd with me.

III.

The cauſe of the air's condenſation confeared, with the aicent of water by cold, in the common thermometer.

'Tis certain that the moſt obvious phenomena of common weather-glaſſes have not been hitherto ſufficiently examin'd. There are three remarkable opinions as to the reaſon why the liquor of this *inſtrument*, aſcends with cold, and deſcends with heat; the firſt whereof is that of the ſchools, which ſuppoſes the cold of the external air to contract that included in the glaſs, and reduce it into a leſs compaſs than before; whence the water neceſſarily aſcends to fill the *vacuum*. But this, we ſee, is not the caſe in the *Torricellian* tube; for the mercury here

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opinion is that of Mr. *Hobbs*, when he ſays, "fluid bodies are made "colder by the preſſure of the air, that is a conſtant wind that preſ- "ſeth them:" but we ſhall ſee hereafter that water will be froze, tho' ſealed up in glaſs veſſels, ſuſpended in others, and wholly immerſed in unfreezing liquors; ſo that the water could by no means be raked with the wind, as Mr. *Hobbs* fancies. Beſides, there's no neceſſity for a wind to preſs the water up into the ſhank; ſince it will riſe in a ſtill place without the aſſiſtance thereof. But beſides the deficiencies of this hypotheſis, we find, by experience, that water, poured into a bolt-head till its ball, and large part of the ſtem be filled, will ſhrink by a degree of cold that falls ſhort of freezing, inſtead of riſing higher; and if a mixture of ice, or ſnow and ſalt, be applied to the bottom of a common thermometer, the water will be thereby made to aſcend ſeveral inches in the ſtem. Laſtly, Mr. *Hobbs* ſuppoſes the water in thermometers to deſcend merely by its own gravity; but this alone cannot, in ſome caſes, ſerve the purpoſe, without the aſſiſtance of the ſpring in the included air: for if a thermometer with a large ball, be placed in a window expoſed to the ſun, the ſurface of the water in the tube, will often appear conſiderably below that on the outſide thereof; and conſequently this depreſſure proceeds not from the bare gravity of the fluid, but from the preſſure of the incumbent air. And for a farther proof hereof, if you keep ſuch a glaſs long enough in the ſun's heat, the water will be driven out of the ſhank, and forced thro' that which is external to it, in bubbles; when, if the remaining air be again cooled, by ſetting the glaſs in a place leſs heated, the loſs of the air that eſcaped in bubbles, will permit the water to aſcend higher in the ſhank, than the ſame degree of cold would have before impell'd it. Thus much may ſuffice to ſhew the erroneouſneſs of Mr. *Hobbs*'s notion.

The third opinion is that of ſome ingenious moderns, who account for the aſcent of the water in weather-glaſſes, by the weight of the air; for the coldneſs thereof, ſay they, cauſes the included air to ſhrink into a leſs compaſs; whence the water in a ſubjacent veſſel, is, by the weight of the incumbent air, (which preſſes more forcibly upon all the other parts of its ſurface, than upon that included in the ſhank) impell'd into the part deſerted by the contraction of the air. But this ſolution, tho' ingenious, and true, and preferable to both the former, ſtill appears inſufficient; tho' if we add hereto, the preſſure and ſpring of the external air, not only againſt the ſurface of the water, but alſo that of the included air, it will fully account for the phenomenon: for the preſſure of the continuous air appears remarkably concern'd in contracting that ſhut up in the glaſs; the ambient air retaining its

PHYSICS. whole preſſure upon account of its weight, whilſt the internal, by being cooled, loſes part of its preſſure, by reaſon of its weaken'd ſpring. In ſome caſes it may, alſo, happen that the air, which ſupports the water to be raiſed, will be leſs cold than the included, that is to be condenſed; whence the former will have a ſtronger ſpring, and conſequently a greater preſſure than the latter. The following experiments countenance this ſolution. Fig. 6. 1. Having almoſt filled half a ſix ounce vial with water, we inverted thereinto a ſlender glaſs pipe, ten inches long, ſealed at one end, and filled full of water by the other, which was immerſed, ſo that no air remained at the top of the tube; when, the neck of the vial being well cemented, we plunged the bottom of the inſtrument in ſnow and ſalt, 'till the included water began to freeze both at the top and bottom: but the water in the pipe did not deſcend; ſo that either the air never ſhrunk, by ſo great a degree of cold, or the water did not remove out of the pipe to poſſeſs the place deſerted by the cooled air. We afterwards attempted to repeat this experiment in the ſame inſtrument, but the ſealed part of the tube being broke in our abſence, (by the ſwelling, as we ſuppoſed, of the water, upon freezing,) prevented us.

2. We, therefore, faſten'd into the ſame vial, a pipe ſome inches longer than the former, but drawn very ſlender at the ſealed end; when, having ſet the vial to freeze, as before, without finding the water deſcend in the tube, we broke off the ſealed end, upon which the water was ſwiftly depreſs'd to the depth of ten inches; but ſo that it yet continued conſiderably higher than the ſurface of the water in the vial. After this, by rarifying the air in the vial, and blowing into it thro' the pipe, the water roſe, almoſt, to the top of the tube; the ſlender end whereof being ſealed, the vial was again placed in ſnow and ſalt: but the ſpring of the rarified air at the top, was ſo weakned by the refrigeration, that it could not ſenſibly depreſs the water; wherefore breaking off the ſealed apex, as before, the external air immediately ſunk it ſeveral inches.

3. For a farther experiment we left, in the ſame pipe, about $3\frac{1}{2}$ inches height of air very ſlightly rarified; when, again, placing the vial in ſalt and ſnow, we obſerved that the air in the pipe expanded it ſelf very little, upon the refrigeration of that in the vial, tho' the water in the vial were conſiderably froze; but upon breaking the ſealed end, the external air preſently depreſs'd the water above two inches below its laſt level: and removing the glaſs into a warmer room, the water aſcended above an inch higher than the ſame uppermoſt level; whence we, with ſome probability, concluded our thermometer ſtanch.

Fig. 7. 4. Having poured a proper quantity of water into a glaſs, reſembling the bolt-head of a common thermometer, except that its ſmall end was drawn very ſlender, which we hermetically ſealed; and inverting the glaſs, the water fell to this end, and poſſeſs'd its due ſpace in the pipe.

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gerated, yet the water did not manifeſtly riſe; and if it had, that might very well proceed from an expanſion of aerial particles which uſually remain in common water, occaſion'd by the diminiſhed preſſure of the air above the ſurface of the water, whilſt the ſpring of that air was weaken'd by the cold. But, to compleat the experiment, breaking off the ſlender end of the glaſs, under water, (whereby the included air became contiguous to water, which immediately communicated with that, whoſe ſurface was every where preſs'd by a column of the external air incumbent thereon,) the water was ſuddenly impelled into the pipe, to the height of ſeveral inches.

5. We procured ſeveral glaſs bubbles of various ſizes, each of them furniſhed with a long ſlender ſtem, whereinto we conveyed a drop or two of water, which was there kept ſuſpended, ſo as to manifeſt the ſmalleſt changes in the rarifaction or condenſation of the air, whereto it was contiguous. Now when the pendulous water here, approached near the top of the ſtem, we could, in an inſtant, with the flame of a candle, ſeal up the orifice thereof; and when, having done thus, we placed the glaſs in ſalt and ſnow, yet the pendulous water nearly preſerved its ſtation. But if, with a pair of ſciſſars, the ſealed end were dextrouſly ſnipp'd off, the water would be ſwiftly forced down, ſometimes many inches below its former ſtation, and ſometimes quite into the round end of the glaſs. We farther obſerved, that, not only when theſe thermometers were ſealed, the uſual degrees either of cold or heat in the air would not, conſiderably, affect the pendulous cylinder, tho', if left open, they ſhew'd, as we ſaid before, the minuteſt differences hereof; but we ſeveral times, ſuddenly, ſealed one up, whilſt the pendulous water was deſcending therein, whereupon its motion would immediately ſtop in that part of the ſhank where it chanced, at that time, to be; and the fluid wou'd there continue till the ſealed end were broken off.

6. We took a large glaſs egg, with a long ſtem, bent in the form of a ſiphon, whoſe ſhorter leg was drawn ſmall, and poured a convenient quantity of water into it, which aſcended to a conſiderable height in both legs; after which, the ſhort one was expeditiouſly ſealed, while a tolerable quantity of air remain'd above the water it contain'd, to impel, by its ſpring, the water into the longer, upon the refrigeration of the air included in the latter. This done, we placed the whole glaſs in a convenient frame, ſo that the oval part was ſupported thereby; whilſt underneath hung the bended ſhank of the glaſs in ſuch a manner, that a mixture of ſnow and ſalt might be laid upon the frame, to ſurround and cool the air, included in the egg, without much affecting that in the cylindrical part of the glaſs; and upon the application hereof, for a proper time, the water in the longer leg aſcended, and the air in the ſhorter, rarified a little: but as ſoon as Fig. 8.

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the ſlender wire, wherein the ſhorter leg ended, was broke off, the external air, ruſhing in, cauſed the water to riſe above 2¼ inches in the longer leg, and then, there not being water enough, broke through it in many bubbles. In which caſe, the aſcent of the water in the longer leg, cannot be attributed to the weight of the air in the ſhorter, becauſe it is vaſtly too ſmall for that purpoſe; but to the ſpring of the ſame. And 'tis not ſurprizing, the expanſion of that air ſhould be ſo ſmall, ſince, as we ſhall ſee hereafter, the refrigeration of the air, in ſuch experiments, is very inconſiderable; whence the air in the longer leg cou'd yield but very little to that in the ſhorter.

From what has been hitherto offer'd, it appears, that the buſineſs of thermometers is, at preſent, but very imperfectly underſtood; and that farther experiments and obſervations are required to ſettle this affair.

IV.

Experiments with bodies capable of freezing others.

All ſublunary bodies, fire alone excepted, are perhaps, at ſome time or other, ſuſceptible of actual cold; at leaſt if our ſenſes were to judge: and even as to fire itſelf, the point muſt remain undetermin'd, till we know whether that be a particular ſtate of matter, as wind, for inſtance, is, or elſe a ſpecies of natural bodies; for ſome ſubſtances, as gun-powder, are inſtantaneouſly turned into fire; and others, as ſpirit of wine, are wholly inflammable, tho' before ignition they were ſenſibly cold, nay gun-powder, if its ſcatter'd parts be collected in a cloſe veſſel, will, immediately after exploſion, give the ſenſation of coldneſs. But our deſign is here not to engage in nice queſtions, but to deliver the phenomena of congelation.

1. There are but few bodies capable of freezing others, in our climate; and among the moſt remarkable, is a mixture of ſnow, and ſalt, which, tho' little uſed in *England*, is frequently employ'd in *Italy*, and other countries, to cool their liquors and fruits, by immerſing them therein.

2. We cou'd not find, upon ſeveral trials, that ſuch glaſſes of water as were eaſily froze by this mixture, wou'd be ſo by ſnow alone. 'Tis poſſible, indeed, in very cold countries, that both ſnow and beaten ice may freeze water poured in the interſtices of their parts; but there's a wide difference between this caſe, and only ſurrounding a veſſel of water with the mixture: and perhaps the ice and ſnow of frigid climates may have a greater degree of coldneſs, than they have in *England*. And tho' a veſſel of water, buried all night in ſnow, ſhou'd freeze, the effect muſt not be wholly attributed to the ſnow, if the coldneſs of the air wou'd, alone, have produced it, and did at all contribute thereto.

3. 'Tis not only ſea-ſalt that added to ſnow, will increaſe its freezing faculty; for ſeveral other things have the like virtue: nitre, alum, vitriol, ſal-

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ſal-armoniac, and even ſugar, may here be ſubſtituted for common ſalt, tho' not, perhaps, to equal advantage. PHYSICS.

4. Spirit of ſalt, tho' it ſuddenly diſſolves ſnow, yet, upon account of its fluidity, cou'd not, in the uſual manner, be detain'd long enough thereon to freeze even a very ſmall quantity of water.

5. We, therefore, put ſome ſnow into a thick, green, glaſs vial, and mix'd with it a proper quantity of weak ſpirit of ſalt; then, ſtopping the veſſel, we ſhook them well together; yet the glaſs appear'd only bedew'd on the outſides, without exhibiting any thing frozen. But ſuſpecting the thickneſs of the glaſs might hinder the effect, we put the like mixture into two thin vials, one whereof was firmly cloſed, and the other ſlightly; when, having long ſhook them, we found what adhered to their outſides thinly frozen.

6. Let it be here obſerved, that in this kind of experiments, the ſnow or ice, included with the ſaline ingredients, was always thaw'd within the glaſs; and that, conſequently, it muſt be the condenſed vapour of the air, or other liquor which adhered to the outſide thereof, that turn'd to ice: and for this reaſon we frequently uſe the word freeze, for the operation of the frigorific mixture, here applied, upon other bodies.

7. Upon mixing ſnow with oil of vitriol, in ſuch a vial as the laſt mention'd, we found its freezing power much greater than that of ſpirit of ſalt. And to ſhew that, in theſe experiments, the cold was tranſmitted thro' the ſides of the glaſs, and that the air included, being greatly cooled by the mixture, did not by communication enable the air contiguous to the outſide of the vial, to freeze the dew thereon; we ſeveral times ſealed up the containing veſſel, and afterwards froze, by means of this mixture, the external moiſture.

8. Spirit of nitre, we obſerved, froze more ſtrongly than either oil of vitriol or ſpirit of ſalt, and continued this virtue till the included ſnow, that lay oppoſite thereto, was almoſt wholly diſſolved: and this we experienc'd, not only in a thin, ſealed glaſs, but alſo in a tolerably thick one, ſtopp'd with a cork.

9. We afterwards ſucceſsfully made the experiment with ſpirits leſs acid, as that of vinegar, and the red empyreumatical one of ſugar; but the films of ice, with the latter, were very thin, and apt to vaniſh.

10. Urinous volatile ſpirits were next made uſe of. Spirit of urine and ſnow being agitated in an open vial, diſcernably froze the external moiſture; but with ſpirit of ſal-armoniac, *cum calce*, the effect was quick and ſtrong.

11. Acid and volatile ſpirits having been tried apart, we alſo try'd them in conjunction. Pouring ſome ſpirit of urine and oil of vitriol upon ſnow, and ſhaking them together in an open vial, the mixture did freeze, tho' very faintly.

12. Some

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PHYSICS.

12. Some trials also were made with the grosser salts, as *Sal Gem*; a sublimation of sal-armoniac and common sublimate, sugar, &c. with all which, the experiment succeeded. A very strong solution of pot-ashes, also, mixt with snow in an open single vial, froze, tho' faintly; and a solution of pure salt of tartar, managed in a like manner, produced thin films of ice.

13. Having fill'd a single vial with snow, we poured thereto a proper proportion of a very sweet solution of *Minium*, made with spirit of vinegar; when, shaking them together, we found films of ice on the outside of the glass; tho' a parcel of the same solution, kept for several hours in snow and salt, was not thereby frozen. In search of the cause whereof, we sealed up a single vial of pure snow, which thaw'd much more slowly than any of those parcels wherewith salts or spirits had been mix'd. And so far as my observation reaches, no salt, that promotes not the dissolution of snow, will enable it to produce ice, tho' it causes dew on the outside of the containing vial; thus, neither crystals of tartar, nor borax pulverized, nay, nor sublimate, wou'd dispose snow to freeze, but lay, for a considerable time, undissolv'd therein.

14. Lime-water, twice tried, wou'd not make snow freeze; but this liquor was above a year old, whence probably its spirit might have evaporated. But all the vials that froze not, collected store of dew, which I attribute to the sole melting of the snow.

15. Nor wou'd distill'd oil of turpentine cause snow to freeze.

16. Sealing up a convenient quantity of pure spirit of wine in a vial, almost fill'd with snow, we observed the freezing virtue of the mixture to be greater than any hitherto mention'd; its effect was also lasting, and that too in another vial that was left open; but the sealed up parcel, crusted over the outside of the glass with ice, which we took off in flakes of a considerable breadth and thickness; nay, it immediately froze urine into figured ice, that might be scraped from the glass.

17. Happening to mix snow with a lucky proportion of spirit of nitre, it froze with that suddenness and vigour, as, in an instant, to fix the vial to the floor, 'twas set on; when, bedewing the outside of the glass with spirit of vinegar, it froze into tolerably thick ice, retaining the salt taste of the spirit. This mixture, indeed, wou'd not discernably freeze spirit of nitre on the outside, tho' it did a weak spirit of salt, and presently turn'd other saline liquors into figured ice, representing small circles crossing each other, and suddenly vanishing. Spirit of sal-armoniac, made with lime, was also congealed hereby, whereupon it shot into branches, almost like those of sal-armoniac, or the like undistill'd salts dissolv'd. And it was pleasant to see, how, upon inclining the glass to let the freezing mixture rest near any part of the spirit, the liquor wou'd suddenly shoot into ramifications, so that the eye

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mented liquors being, alſo, applied to ſnow, inſtead of ſpirit of wine; the experiments ſucceeded not with ſmall beer, but wine and moderately ſtrong ale produced a ſlight ice.

18. Obſerving that whatever haſten'd the diſſolution of the ſnow, generally promoted its freezing, 'twas thought proper to try what wou'd be the event of ſuddenly diſſolving ſnow by bodies actually warm. Into a ſingle vial almoſt fill'd with ſnow, we poured a tolerable quantity of heated ſand, to diſſolve the ſnow in many places at once, without heating the external air, or the outſide of the glaſs; and tho' the ſolution of the ſnow was hereby promoted upon ſhaking the veſſel, yet the outſide of the glaſs was only bedew'd, not frozen.

Into another vial almoſt fill'd with ſnow, we poured warm water, that it might fall upon the middle part thereof; then taking a convenient time to ſhake the glaſs, we, by this means, produced a very conſiderable degree of cold, and much dew on the outſide, but cou'd not be certain it was frozen; tho' the experiment deſerved to be repeated.

19. 'Tis a popular opinion, that the hoar-froſt, viſible upon glaſs windows in a froſty morning, is an exudation of the glaſs, condens'd and froze into various figures, by the cold external air. But the ice lies not on the outſide, but inſide of the windows, where 'tis generated of the watery particles floating in the air of the room, and by their proper motion paſſing along the ſurface of the glaſs, where they are, by the vehement cold of the adjacent, external air, communicated thro' the glaſs, condenſed into dew, and frozen into ice.

20. Many modern naturaliſts hold, that glaſs is eaſily pervious to air, and ſeveral ſubtile liquors, who may, therefore, aſſert that the ice in our experiments proceeds from the fine parts of the cold mixture paſſing thro' the pores of the glaſs, and ſettling on the outſide thereof. But the following experiments will ſhew the falſity of this doctrine.

21. A mixture of ice and ſalt, weighing four ounces and a quarter, being included in a vial, and condenſing the vapours of the external air, thereby increaſed its weight twelve grains. Another vial of ſnow, that weighed two ounces, ſix drams, and a half, by condenſing the vapour of the external air, augmented the weight of the vial and its contents four grains; and in the ſcale, we found the water flowing from the dew, which gave this increaſe of weight. The tip of this ſealed vial being broken under water, a conſiderable quantity of that fluid was drawn in; whether upon account of ſome ſmall rarifaction of the included air, cauſed in the ſealing, or of its coldneſs receiv'd from the ſnow, or both together, I ſhall not now inquire.

22. Others

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PHYSICS.

22. Other experiments were made, wherein this increaſe of weight was more conſiderable. We ſealed up as much ſnow and ſalt, in a ſingle vial, as, being afterwards melted, weighed between five and ſix ounces; and the ſolution beginning to be made, the dew on the outſide began to congeal, and when rubbed off, the hoar-froſt would preſently appear again. We next ballanced this glaſs in a pair of ſcales, when, as the external vapour of the warm room condens'd to its ſides and froze, the ſcale containing the glaſs ſunk gradually lower; but by adding weights in the other, we again reduced them to an equilibrium; tho' the former wou'd ſoon after deſcend; till the included ſnow was thaw'd; ſo that the whole weight required to bring the balance even, was about eight or ten grains. The vial being then taken out, there appeared near half a ſmall ſpoonful of liquor in the ſcale wherein it ſtood, occaſioned by the thaw of the ice generated on its ſides; but no moiſture appear'd in that part of the ſcale that was covered by the convex part of the bottom of the glaſs.

23. A like quantity of ſnow being ſealed up with ſpirit of wine, in a ſingle vial, the outſide was preſently caſed with ice to the ſame height that the mixture ſtood within: this vial alſo was counterpoiz'd, and ſunk as the former, and about ſeven grains were required to reduce the balance to an equilibrium.

24. When the experiment happened to be more luckily made, this increaſe of weight was ſtill greater. At one time, when the mixture of ſnow and ſpirit of wine weighed three ounces and three quarters, it afforded eighteen grains of condenſed vapours. At another time a mixture of ſnow and ſal-gem, that weighed three ounces and ſeventy grains, gave an additional weight of twenty grains of water*.

V.

Experiments and obſervations upon bodies diſpoſed to be froze.

1. Different bodies will freeze with different degrees of cold; but it were endleſs to try, particularly, what ſubſtances are capable of congelation, and what not: but not to leave this part of our hiſtory untouch'd, we ſhall mention a few.

2. In very cold ſnowy weather, we obſerved water, urine, beer, ale, milk, vinegar, *French* wine and *Rheniſh*, to be either wholly, or in part, converted into ice, tho' the two laſt but ſlowly. We alſo froze a

* Something like theſe experiments, whereby a great degree of cold is produced, ſeems to be done by nature in a cave, in *Franche County*, fifteen miles from *Beſanſon* to the *Eaſt*. In this cave it is exceſſive cold in ſummer, and proportionably colder as the weather abroad is hotter. For the place abounding in nitrous ſalt, or ſal-armoniac, and eſpecially the top of the cave, the heat of the ſummer putting this ſalt in motion, it mixes and unites with the water that runs down the ſides and cleſts of the rock into the cave, and there congeals into ice. *Hiſt. de l' Academ.* A. 1712. p. 27 —— 29.

ſtrong

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ſtrong ſolution of gum-arabic and white ſugar, made in common water; and expoſed to the cold air, the like ſolutions of alum, vitriol, ſalt-petre, ſea-ſalt and verdigreaſe in ſingle vials: thoſe made with the alum, nitre, and verdigreaſe, froze without any remarkable phenomena; in that of vitriol there remain'd, at the bottom of the glaſs, a conſiderable quantity, clear and unfrozen, the colour whereof ſhew'd it to be greatly impregnated with the vitriol, while the upper part of the ſame differed little in colour from common ice. PHYSICS.

3. Not only theſe groſſer ſaline bodies were thus expoſed, but alſo ſuch as had been refined by fire. Spirit of vinegar, and ſpirit of urine, being expoſed, in ſeparate glaſſes, to an intenſe cold, we obſerved them both to be frozen.

4. To two ounces of water we added a dram of the fiery lixiviate ſalt of pot-aſhes, and expoſed them to a very ſharp air; when coming to examine the ſucceſs, we found little ſticks of ice upon the top, like the cryſtals of rock nitre, whilſt others ſhot downwards in great numbers.

5. Oil of tartar *per deliquium*, tho' it ſeem'd greatly to reſiſt the cold, was, notwithſtanding, once brought to congeal by ſnow and ſalt.

6. As to the freezing of common expreſs'd oils, I know not what to determine. That they may, by a very intenſe cold, be deprived of their fluidity, ſo as to be cut into portions of any figure, my own experiments perſuade me. But whether they are convertible into real ice, is a queſtion undeterminable by any trials we could make in *England*. I am informed, by the *Ruſſian* Emperor's phyſician, that oil in *Muſcovy*, freezes much harder than with us; but will not there become perfect ice: on the other hand, Captain *James* tells us expreſly, that in the iſland where he once winter'd, "their oil, as well as every other li-"quid, was frozen ſo hard as obliged them to cut it with a hatchet." And *Olaus Magnus* relates, that "in the battles fought upon the ice, in "the northern regions, the ſoldiers wear not leather, but woollen harneſs "on their legs; becauſe," ſays he, "the cold, in theſe parts, gives the "ſlipperineſs of ice to whatever is dreſs'd with oil." Common aniſeed-water, and the like weak ſpirits, will, by the cold in *Muſcovy*, according to the relation of the phyſician above-mentioned, be turn'd into an imperfect ice; and the ſtronger ſpirits into a ſubſtance like that of oil.

7. A ſolution of *minium*, made with ſpirit of vinegar, was, upon the 26*th* of *December* in the morning, tho' it ſtood near the fire, ſo ſtrongly frozen, that part thereof appear'd ſhot into *Saccharum Saturni*; whilſt a ſmall quantity remain'd on the top unfrozen, of a yellow colour; which being poured out, did not congeal.

8. A ſolution of gold, made with ſalts, that ſtood with the ſolution of *minium*, was alſo frozen.

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9. A quantity of the tincture of *Lignum Nephriticum*, that filled a pint vial, being froze, exhibited no colour in the ice, whilſt it remain'd fluid.

10. Mr. *Drummond* inform'd me that he had often ſeen wine, and brandy, frozen in *Ruſſia*; but that the ice of the latter was leſs hard than the common ſort.

11. A *French* chirurgeon told me he had ſeveral bottles of brandy frozen in *Ruſſia*; whilſt a liquid part retired to the center, and appeared to be ſpirit of wine, vaſtly ſtronger than common brandy.

12. The *Ruſſian* Emperor's phyſician acquainted me, that on the *7th* of *December*, having put ſome *French* brandy into a *China* cup, and expoſed it to the air, it was in three hours time, turn'd into a cruſty ice upon the ſides of the cup; and that expoſing water and ſallet-oil together, the latter was reduced to the firmneſs of tallow, while the former remain'd unfrozen.

Solid bodies frozen.

13. As to the freezing of ſolid bodies, we have ſometimes tried it by expoſing wood, and branches cut off from growing trees, to an intenſe degree of cold, by which they ſeemed, in one night's time, to be, for ſome little depth, manifeſtly invaded by the froſt. But a domeſtic of mine having, lately, felled an old apple-tree, on a day that had been preceded by a fortnight's bitter froſt, inform'd me, that he found the froſt had pierced the very middle of it, tho' it was a foot diameter. And an experienc'd artificer in building, told me he had often ſeen, here in *England*, pieces of timber apparently frozen, and render'd exceeding difficult to be ſawed; the froſt alſo evidently continuing in the ſaw-duſt. And, therefore, it will be the leſs ſtrange if, in *Poland*, the effects of cold upon wood, be more conſpicuous. A learned native aſſured me, that it was there uſual to have wood frozen ſo hard, that the hatchets wou'd not cut, but rebound from it: he told me, alſo, that he had ſeveral times ſeen pieces of timber, which, having been throughly frozen in the air, and afterwards brought into warm rooms, were covered with a kind of hoar froſt, which made them look white. He added, that his bow, which I ſaw, was very ſtrong and tough, for it conſiſted of horn and other cloſe materials, would be ſo changed by the froſt, that unleſs ſpecial care were had in thawing of it, it would break.

14. That marle, chalk, and other leſs ſolid terreſtrial concretions, will be ſhattered by ſtrong and durable froſts, is obſerved by huſbandmen, who find them thereby the better fitted to manure their land; the texture of thoſe bodies being, by congelation, in great part diſſolv'd: but that true and ſolid ſtones, ſuch as are employed in noble buildings, ſhould be ſpoiled by the froſt, will, perhaps, ſeem very improbable; yet I have learned from a moſt ingenious and experienc'd maſon, that he had often obſerved, both free-ſtone, and harder ſtones than that, to be exceedingly ſpoiled by the froſt, and reduced to

crack

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bricks in *England*, chiefly conſiſt of theſe ſtones, and yet very well endure the inclemencies of the air; we muſt obſerve, that the difference may not depend upon the peculiar nature of the ſtones employ'd, but on the ſeveral ſeaſons in which they were dug out of the quarry. For if they be hewn out of the rock in cold weather, and employed in building the ſame winter, they will, upon very hard froſts, be apt to ſhatter or ſcale; but if dug early in ſummer, and ſuffered to lie expoſed to the ſun and air, during all the heat thereof, they will thereby be ſeaſoned, and made able to endure many ſharp winters unimpaired. It ſeems to me worth trying whether, during their lying expoſed to the ſun, they do not exhale a certain unripe mineral ſap or moiſture, which, remaining in the ſtone, may, by very piercing froſts, be congealed and ſhatter its texture. This ſeems agreeable to what an underſtanding perſon, who is maſter of a great glaſs-houſe, told me, of his great earthen pots, which are made up with as little water as poſſible, and thence become deſervedly famous for their durable texture; for he aſſured me that if he did not take care to keep the froſt from getting into them, thoſe ſolid veſſels wherein he uſed to keep his glaſs infuſion, would, in the fire, ſcale, crack, or fly; and become unſerviceable ſeveral weeks ſooner than if they had never been impaired by the froſt. He, alſo, affirmed that in very hard froſts ſeveral glaſſes that had continued intire for many weeks, would, as it were of their own accord, crack with a loud noiſe.

To this may be added, the teſtimony of an experienced *French* author, *Bernard Paliſſy*, who tells us, "that the ſtones of the mountains of *Ardenne*, are harder than marble; and yet the inhabitants of that country do not take them out of the quarry in the winter, becauſe they are ſubject to the froſt; and that it has often been found upon thaws, that the rocks, without being cut, have fallen down, and thereby killed many perſons." It may ſeem far more unlikely, that froſts ſhould get into metals themſelves; yet the *Polonian* lately mention'd, aſſured me, that upon drawing his ſword, or pulling out his piſtols in a warm room, after he had been long in the field, he has preſently found them almoſt whitened over by a kind of ſmall hoar-froſt. But if we credit *Olaus Magnus*, conſiderably thick pieces of iron and ſteel will, in the *Northern* regions, be rendred ſo brittle, by extreme froſt, that they are there obliged to temper their inſtruments after a peculiar manner. And even here in *England*, I have cauſed trials to be made in very froſty weather, whereby, if an expert ſmith, I then employ'd, did not wilfully deceive me in the iron, that metal may, by ſuch degrees of cold as even our climate affords, be rendered exceeding brittle: and he ſeveral times affirmed to me, that there are ſome kinds of iron which he could hammer and turn, as they

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PHYSICS. phraſe it, cold in open weather, which yet in very hard froſts, would become ſo brittle as, by the ſame way of working, eaſily to break or fly aſunder; and this he aſſerted both of iron and ſteel; as to the latter of which, another very ſkilful workman certified the like. And for further ſatisfaction about this matter, I enquired of a very dexterous artificer, well ſkill'd in making ſprings, whether he found a neceſſity of giving them a different temper in very froſty weather; who told me, that to prevent their breaking in ſuch weather, he was obliged to let them down lower than at other ſeaſons; which makes it probable, that cold may have a conſiderable operation upon bodies where it is not ſuſpected. And this affords a hint that may poſſibly reach further than we ſeem to be aware of; as to the ſhare that quality may have in producing many phenomena of nature.

VI.

Experiments upon bodies indiſpoſed to be froze.

1. We found many diſtilled ſpirituous liquors, well freed from phlegm, which diſpoſes bodies to congelation, cou'd not be brought to freeze, either by the cold of the open air in froſty nights, or ſuch an application of ſnow and water as ſerved to freeze other ſubſtances.

2. Of this kind were *Aqua fortis*, ſpirit of nitre, ſpirit of ſalt, oil of turpentine, and almoſt all the chymical oils. Spirit of wine alſo, and of other fermented liquors, would not congeal; and even ſack it ſelf, if good, would ſcarce afford any ice at all. But after burning away ſome of the more ſpirituous parts of a quantity of this wine, that would yield no ice, the remaining portion was eaſily brought to freeze. Having expoſed two drams of pot-aſhes diſſolved in one ounce of water, the vial that contained them was cover'd with hoar-froſt and ice on the outſide; but the mixture froze not a whit within. At another time, a very ſtrong ſolution of ſalt of tartar kept fluid, whilſt a tolerably ſtrong ſolution of pot-aſhes, that was expoſed therewith, froze. Theſe experiments, therefore, with lixiviate liquors, ſhou'd be repeated, to reduce them to a certainty.

3. Train-oil, which is made, by the help of fire, from the fat of the whale, expoſed twice or thrice in a vial to a very cold air, continued fluid; 'till at length, the night proving exceſſive cold, 'twas congealed the next morning. But what credit does this bring to the report of *Olaus Magnus*, who tells us, 'tis uſual in the northern regions to fill up the frozen ditches of fortified places with train-oil, in the winter, to preſerve the lower water fluid, and keep the enemy from paſſing them. 'Tis however worth enquiry, whether the whale-oil uſed by the *Swedes*, *Laplanders*, *Muſcovites*, &c. be different from ours, unleſs *Olaus Magnus* may be juſtly ſaid to have often impoſed upon his reader.

4. A ſtrong ſolution of common ſugar was eaſily converted into ice, but one of *Saccharum Saturni*, cou'd not be thus alter'd by ſalt and ſnow; which is the more remarkable, becauſe of the two ingredients

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kind of vitriol of lead, 'tis remarkable, that its ſolution ſhou'd not freeze, as well as that of common vitriol, when to make the latter, metal is corroded by a ſpirit probably much ſharper and ſtronger than that of vinegar.

5. We, likewiſe, attempted to freeze quick-ſilver; and for that end, provided a thin bubble blown ſo flat, that its oppoſite ſides almoſt touch'd each other, which, therefore, contain'd but a ſmall quantity of mercury, ſpread out into a large ſurface, to receive the action of the cold: but our endeavours herein prov'd fruitleſs, tho' the laſt trial was made in the ſame intenſe degree of cold, with one of the following Experiments. Having long expoſed another thin glaſs bubble of quick-ſilver to a vehemently ſharp air, the cold had ſome ſmall effect thereon, but wou'd not bring it to freeze; wherefore, I wiſh that the trial were made in *Muſcovy*, *Greenland*, *Charles-Iſland*, or the moſt frozen regions.

6. 'Tis remarkable, that tho' ſolutions of many groſs ſalts, and even the more ſaline and ſpirituous liquors, are, by ſnow and ſalt brought to congeal; yet a very ſtrong brine of common ſalt never froze at all, tho' expoſed with other ſaline ſolutions, that were turn'd to ice, in an exceeding ſharp night. But expoſing a ſolution made of one part of ſea-ſalt, and twenty of water, in a ſingle vial, to the air of a very intolerable cold night, we on the next day found a great portion of the liquor frozen; the ice floating on the top in figures, reſembling thoſe of broom, and ſpreading downwards from the ſurface of the water. And, by the way, we permitted the ice of ſalt-water to thaw, in order to ſee whether it wou'd yield freſh; but it ſtill retain'd ſome brackiſhneſs; which, whether or no it proceeded from the brine contiguous to the ice, I leave to be determined; being credibly inform'd, that the thaw'd ice of ſea-water is often uſed in *Amſterdam* for brewing. And *Bartholine*, in his book *de Nivis uſu*, confirms this relation, in the following words. "'Tis certain," ſays he, "that if the ice of ſea-wa-"ter be thaw'd, it loſes it ſaltneſs; as has been lately tried by a pro-"feſſor in our univerſity.

7. Spirit of ſal-armoniac with quick-lime, volatile oil of amber, a little oil of vitriol, a ſolution of ſilver in *Aqua fortis*, ſome diluted rain water, and a vial full of weak ſpirit of human blood, were expoſed for two nights and a day, to the cold; whereby the three former were not at all frozen, but the ſolution of ſilver was congealed, and the ſpirit of human blood almoſt wholly converted into ice, which roſe ſo high, as to thruſt the cork out of the vial that contained it.

8. Unrectified oil of turpentine, tho' expoſed all night in a ſingle vial, would not freeze; yet the ſame quantity, ſet in an earthen veſſel, had its upper part turn'd to tolerably thick ice, figured almoſt like that of frozen urine.

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9. A traveller inform'd me, that in a part of *Scotland*, there is a lake, from which iſſues a ſmall river, neither of thoſe waters are ever froze in the depth of winter, which is there exceſſive ſharp: he adds, that lumps of ſnow and ice, caſt into the lake, do readily diſſolve therein; and that this water differs not, in taſte, from the common.

10. A commanding Officer inform'd me, that his ſoldiers making uſe of ſallet oil to the locks of their muſkets, could not make them diſcharge; but being adviſed to apply hemp-oil, they froze not therewith: nor, as I am told, will train-oil freeze.

VII.

Experiments and obſervations of the degrees of cold in ſeveral bodies.

1. Having already treated of thermometers, and the methods of applying the nicer ſort, to eſtimate the different degrees of coldneſs, both in ſolid and fluid bodies, we need only here farther add, that when they are uſed in conſiſtent ſubſtances, we alter the figure of the round bubble into a flat bottom, that the whole inſtrument may reſt thereon; due care being always had to take it up by the ſlender end, for fear of rarifying the included air: and thus it may be transfer'd with a pendulous drop in the pipe, from one ſolid body to another.

2. To make a tolerable eſtimate of the difference between ſuch high degrees of cold, as will all ſuffice to congeal water, is a difficult taſk; for freezing having been commonly reputed the ultimate effect of cold, men have ſeldom look'd beyond it. The difference between different froſty ſeaſons are too manifeſt, and frequent, to be wholly aſcribed to the different tempers of our bodies; yet how to eſtimate that difference, is not ſo obvious. The common weather-glaſſes, we have formerly ſeen, may eaſily deceive us herein. Some gueſs, indeed, might be made by the operations of cold upon liquors, yet ſome will freeze too ſuddenly, and others not at all in *England*.

3. Upon theſe and the like conſiderations, we thought proper to employ an expedient, the nature and uſe whereof will appear from the following experiments. And tho' a miſchance prevented me from determining exactly, how much the ſpirit of wine in my thermometer was contracted, in proportion to its whole bulk, by the exceſs of cold, above what was neceſſary to freeze common water; yet ſomething of uſe to the preſent ſubject may be thence collected: and particularly, the chief thing will manifeſtly appear therefrom; that is, the intenſeneſs of cold, produced by art, beyond what nature neceſſarily employs, to turn water into ice.

4. We took a ſmall ſealed thermometer, furniſh'd with ſpirit of wine, a ball about the bigneſs of a large nutmeg, and a very ſlender cylindrical ſtem, ten inches long; and immerſing the ball and part of the ſtem in a veſſel of water, half buried in ſnow and ſalt, the water began

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out, and ice and ſalt immediately applied to the ball, the ſpirit fell 1 ½ diviſion lower. And that the water, tho' in part congealed, remain'd warm, in compariſon of the ſpirit of wine, which was fluid, tho' refrigerated by the ſnow and ſalt, appears from the following experiment.

5. The glaſs continuing in the water till that began to freeze, deſcended to 5 ½; when, being immediately removed into the ſame ſnow and ſalt, which reduced the water to that ſtate at firſt, the ſpirit deſcended very ſwiftly, but afterwards more ſlowly, till it fell to the very bottom of the ſtem; 'twas then removed into the ſame glaſs from whence we took it, wherein were many looſe pieces of ice; nevertheleſs it haſtily aſcended at the firſt, and was, preſently after, impell'd to the former height of 5 ½ diviſions.

6. The condenſation of liquors, by ſuch degrees of cold as are procurable among us, is nothing near ſo great as might be imagin'd. On a cold day, but not froſty, having very carefully weigh'd a ſmall round veſſel of clear glaſs, furniſh'd with a long ſtem, and found its balance to be one ounce, one dram, 56 ½ grains, we fill'd its round part with well rectified oil of turpentine, till it aſcended a little way up the ſtem; exactly marking its ſtation, with a diamond on the outſide of the glaſs: we then put them both into the ſcale, and found them to weigh two ounces, ſeven drams, 34 ½ grains; when gradually pouring in ½ dram of oil, mark'd how high it reach'd in the pipe, and ſo continued to add ſeveral parcels of the ſame fluid, always carefully weighing each quantity, and marking its height on the outſide of the glaſs, till the liquor and glaſs together weigh'd three ounces, one dram, 4 ½ grains. The little bolt-head was now placed with its ſpherical part in a wide-mouth'd glaſs of fair water; when, by laying ſnow and ſalt around it, we made the water begin to freeze, till a little ice was produced thereon; then carefully marking the part of the ſtem whereto the oil had deſcended, we transfer'd the bolt-head to a mixture of ſnow and ſalt, where 'twas kept for an hour or two, till we perceiv'd it fall no lower; and marking this ſtation alſo, we afterwards removed the glaſs into a warmer air, till the oil had regain'd the higheſt mark from whence it began to ſink. We next gently poured out of the bolt-head, into a very ſmall glaſs nicely counterpois'd in very tender ſcales, ſo much of the oil till the remainder reſted againſt that mark of the ſtem, whereto it fell when the water began to freeze, which amounted to 9 ½ grains, tho' we might ſafely call them ten. After this, we poured more oil out into the ſame little glaſs, till what was left in the pipe, ſtood even with that mark whereto the ſnow and ſalt had ſunk it; which parcel of oil happen'd to be very nearly of the ſame weight with the former; ſo that the artificial

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PHYSICS. way of freezing, employ'd in this experiment, made the oil ſubſide as much, after it had been refrigerated and condenſed by a degree of cold capable of congealing water, as that degree of cold had been able to condenſe it at firſt. And, laſtly, having deducted the weight of the glaſs from that of the whole oil and glaſs together, to gain the weight of the oil alone; and having divided the weight of the whole oil, firſt by that of the former parcel of ten grains, and then by the weight of the ſecond; we found that rectified oil of turpentine, of a moderate temper, expoſed to a degree of cold capable of freezing common water, did, by contraction, loſe a 94th part; and that being reduced to as great a coldneſs as ſnow and ſalt cou'd bring it, it even then loſt but about a 47th part of its bulk.

7. Another attempt we made to meaſure the proportion, whereto water of a moderate coldneſs wou'd ſhrink by the force of ſnow and ſalt, before it began to expand by congelation: and by a trial purpoſely made with common water in a round glaſs furniſhed with a long ſtem, we found the water in that ſtem to ſubſide ſo very little as to be inconſiderable; but probably a larger quantity of water and a ſlenderer ſtem, wou'd have render'd the contraction of the liquor more remarkable.

8. We alſo try'd to meaſure, by the different weight and denſity of the ſame portion of water, the change therein produced between the utmoſt heat of ſummer, the firſt degree of freezing cold, and the higheſt that art can create. And in order hereto we weigh'd, with a pair of exact ſcales, a glaſs bubble heavier than water, in that fluid, when it was of a moderate coldneſs, and thereby readily gain'd its proportion to an equal bulk of that water; then, by applying ſnow and ſalt, we made the water begin to freeze, and again weigh'd the bubble therein, to find what proportion an equal bulk of the cooled liquor wou'd bear to the glaſs; and by comparing theſe two proportions together, we made an eſtimate of the water's increaſed gravity and denſity by the action of a freezing degree of cold. In the following ſummer, we deſign'd to have weigh'd the bubble in the ſame parcel of water, that, by the difference of its weight therein, when render'd lighter by the heat of the air, we might obtain the information we deſired. This experiment I, alſo, recommended to be made in *Italy*, during the ſummer's heat; ſnow being there eaſily procurable at that time; but having hitherto receiv'd no advice of its being perform'd, nor been able to perfect our own experiment, I content myſelf with ſhewing the ſteps we deſign'd to purſue therein.

9. Whether the making of ſuch experiments as theſe, with the waters of particular rivers or ſeas, may afford any uſeful inſtruction, as to the greater burthen a ſhip will carry thereon, in winter than in the ſummer, is an inquiry which I ſhall not here inſiſt on: we may, however, obſerve, that the difference betwixt water cold in the extreme degree,

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weigh'd, in common water, a glaſs bubble, whoſe weight in air was 150 grains; but in water only 28 ½ grains, and then by ſnow and ſalt made that water begin to freeze in an open glaſs, we found the bubble weigh'd therein not above ½ grain leſs than before; ſo that if we may judge of the condenſation of water by the increaſe of its weight, this ſhrunk only about a two hundred and thirtieth part of its former bulk.

VIII.

Experiments relating to the tendency or direction of cold.

We come now to conſider in what line of direction the refrigerating power of cold bodies acts with the greateſt force, or to the greateſt diſtance. That heat diffuſes itſelf principally upwards, is a known doctrine, and uſually holds true; whence it might be ſuſpected, that cold had its tendency chiefly downwards. With relation to this point, we made the two following experiments.

1. A very thin bubble, made flat at the bottom, that it might be the more expoſed to the cold, being filled with water, and ſuſpended by a ſtring, at the diſtance of an inch, above a mixture of beaten ice and ſalt, wherewith we had half fill'd a large wide-mouth'd glaſs, the water ſhew'd no ſigns of being froze. And to this experiment agrees an obſervation we made, that a mixture of ice and ſalt did not congeal the vapour of the air, at the diſtance of more than half a barley corn's breadth, above the height whereto the mixture reach'd in the glaſs.

2. We put a mixture of ſnow and ſalt into a vial with a long neck, the round part whereof was by a weight kept under water, from whence being ſoon taken, the outſide of the glaſs, below the ſurface of the water, was found caſed with ſolid ice, and particularly about the bottom of the vial, to a vaſt thickneſs and hardneſs.

3. From hence, however, I will not poſitively conclude, that the tendency of cold produced by bodies able to freeze others, is greater downwards than upwards; for I ſuſpect it requires more accurate experiments to determine that matter. How it happen'd I know not, that ice in the laſt experiment ſhou'd be much thicker there than elſewhere; for in other trials of the like kind, we generally obſerv'd the outſides of the glaſſes to be caſed with ice, or cover'd with hoar-froſt on that part directly oppoſite to the ſnow and ſalt, which mutually diſſolving each other in part, and falling in a fluid form to the bottom, the undiſſolved part of the ingredients wou'd float upon this liquor, oppoſite whereto the external ice generated thereby appear'd; ſo that as the mixture grew gradually thinner, the belt of ice on the outſide became narrower, till at length, when the ſnow was quite diſſolved, the ice preſently vaniſh'd. And as in ſuch vials the ice ap-

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PHYSICS. pear'd not, as we ſaid, more than the breadth of half a barley corn above the mixture, ſo neither do I remember to have ſeen it much farther below it; from whence it may, with ſome probability, be ſuppoſed, that the coldeſt bodies diffuſe not their freezing power to any conſiderable diſtance, either upwards or downwards.

4. But the preſent experiment having been made under water, and the others in the open air, I dare not, without farther trial, determine how much this difference of the medium may alter the caſe in the diffuſion of cold; eſpecially ſince we ſhall preſently ſee, that frozen eggs, ſuſpended under water, were every where equally ſurrounded with a coat of ice.

5. A principal obſtacle to the progreſs of the hiſtory of cold ſeems to have been, that the common method of freezing by ſnow and ſalt, is apt, like the ordinary froſt, to break the glaſs veſſels employ'd; for in both caſes the fluid beginning to freeze at the top; and the property of glaciation being to diſtend the liquors it affects; when the upper cruſt of ice is grown thick, and bears hard with its edges againſt the ſides of the veſſel, it makes a greater reſiſtance to the farther expanſion of the fluid, as that is ſucceſſively frozen; whence the containing glaſs is eaſily burſt.

6. For this reaſon, I contrived to freeze the water from the bottom upwards, by mixing the ſalt with that part only, of the ſnow which was to lie under, and about the lower part of the glaſs placed in it. By this means the ſnow, contiguous to the ſides, did no more than cool the water and diſpoſe it to freeze, whilſt that whereon the glaſs reſted, being mix'd with ſalt, converted the adjacent liquor into ice, and ſo raiſed the incumbent fluid; which I cou'd alſo freeze without danger of breaking the glaſs, by barely applying the mixture to its ſides, ſo as not to let it reach too near the ſurface of the liquor, whoſe upper parts were thus kept fluid to the laſt, and therefore, capable of being impell'd, gradually upwards, by the expanſive force of the lower.

7. No nicety of proportion need be obſerved in the quantities of the ſalt and ſnow made uſe of; neither is it requiſite they ſhou'd be intimately mixed: a third or fourth part of the former, to one of the latter, ſucceeds well. I ſeldom add ſalt to all the ſnow, at once, unleſs I deſire an immediate congelation; and by the method above-mention'd, I procure ice on what external part of the glaſs I pleaſe. And let it be obſerv'd, that beaten ice will freeze in this caſe as well, if not better than ſnow; for which reaſon, I promiſcuouſly uſe either of them with ſalt, for the ingredients of our freezing mixture.

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Experiments and obſervations, with regard to the preſervation and deſtruction of bodies by cold.

'Tis a tradition, that frozen eggs or apples are ſpoiled by being thaw'd near the fire, but if immerſed in cold water recover their natural ſtate. Upon more reaſons than one, we thought fit to try the experiment; but the event did not anſwer our expectation: however, after ſeveral attempts, we at length brought it to ſucceed.

1. An egg that weigh'd twelve drams and one grain, being wrapt up in wax'd paper, and frozen with ſnow and ſalt, loſt four grains; 'twas then put into a diſh of fair water, where it gain'd ſuch a coat of ice, as cauſed the whole to weigh fifteen drams, nine grains; then the ice being taken off, and the ſhell very well dried, the egg weigh'd twelve drams, twelve grains. At length we broke it, and found it almoſt entirely thaw'd. When froze, it floated in water, but ſunk when thaw'd.

2. We placed two eggs, ſtrongly frozen, in a room where there was a large fire, one of them plunged in a deep wooden diſh full of very cold water, and the other upon a table near it, about two yards from the fire; when, perceiving that in the water to be cruſted over with ice, we took it out, freed it therefrom, broke it, and found many little parcels of ice remaining upon ſome part of the white; while the other part of the ſame, and the whole yolk, appear'd nearly of the ſame conſiſtence, as if they had never been frozen; but the egg that lay dry, had both its white and yolk entirely frozen; the latter whereof, being as hard as if it had been over-boil'd, ſhew'd us, when cut thro' the middle, ſeveral concentrical circles of different colours, with a ſpeck much whiter than any of them, in its center; which laſt circumſtance was perhaps accidental. By the way, we only once obſerved frozen eggs to ſwim; and that when ſuch eggs were broken, the white floated, and the yolk ſunk.

3. Upon repeating the ſame experiment, we were convinced, that frozen eggs will thaw much ſooner, *cæteris paribus*, when immerſed in water, than when ſurrounded only with air.

4. Suſpending a frozen egg under water, at a diſtance from the ſides of the containing veſſel, its icy coat over-ſpread the thread whereby 'twas hung; and we found that coat of an uniform thickneſs, tho' a conſiderable quantity of ice was generated at a ſmall diſtance herefrom; which ſeem'd to owe its origin to the ſame cauſe; yet we cou'd not find that it any where adher'd to that which immediately cover'd the egg: 'tis poſſible, however, its rudiments were parted from the egg, by ſome motion communicated to the table whereon the experiment was made.

5. Having expoſed ſome pippins, all night, to freeze, and put them on the following morning, into a baſon of very cold water, that ſtood

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PHYSICS. in a warm room, they were ſoon ſurrounded with caſes of ice to a conſiderable thickneſs; and here we obſerved, that the immerſed part of a floating apple was thicker coated with ice than what remain'd above; that the extant part ſeem'd alſo harder than the other; that one being purpoſely laid on the outſide of the baſon, appear'd in cutting to be harder and more frozen than thoſe which had been plunged under water; the latter proving almoſt as ſoft as pippins that had never been froze, but particularly in their external parts; laſtly, that neither theſe, nor frozen eggs, notwithſtanding their great congealing force, upon the contiguous water, appear'd to detain or freeze the vapour of the air, as ice and ſnow mix'd with ſalt, and included in glaſſes, very remarkably do.

6. After freezing ſome eggs in ice and ſalt, till their ſhells crack'd, we plunged one into milk, two into a glaſs of beer, and two more into a glaſs of ſack; but none of them produced a grain of ice. Some others being immerſed in vinegar, the ſaline part of the liquor began to diſſolve their ſhells, whilſt the cold of the ice therein was unable to freeze any part of the fluid.

7. I alſo deſign to try whether pieces of iron of different ſhapes and magnitudes, expoſed for ſeveral nights to the freezing air, and afterwards immers'd in water, wou'd produce any ice; for the froſt ſeems to affect ſuch bodies. And I have been aſſured, that a large cheeſe being buried in water, in a cold country, was immediately cover'd over with ice. But for want of a froſt ſufficiently durable, I cou'd not obtain my deſire. However, I kept large lumps of iron and other metals, pieces of glaſs, and ſome ſtones of a proper ſize, for a conſiderable time, longer in ſnow and ſalt, than wou'd have ſuffic'd to cauſe eggs, apples, *&c.* to produce plenty of ice upon being thaw'd in water; yet we found nothing of this kind upon any of the ſeveral mineral bodies mention'd, tho' kept long cover'd in cold water.

8. Ice and the juice of pippins well ſhook together in a ſingle vial, produced abundance of dew, but no ice.

9. Ice and the white of an egg gently beat into a liquor, did the like; but theſe trials ought to be repeated.

10. That frozen apples are better preſerved by being thaw'd in water, than before the fire, we are convinc'd by ſeveral trials; and cou'd not but wonder to ſee how great a putrefaction was cauſed in theſe bodies by thawing them ſuddenly; but in eggs the experiment is not ſo eaſily or expeditiouſly made.

11. This obſervation ſeems to hold equally in the bodies of men, when froze. 'Tis commonly found in the cold northern climates, that if any perſons, whoſe limbs are froze, approach the fire too haſtily, they thereby endanger the loſs of them. "Upon many of us," ſays Capt. *James*, "the cold had raiſed bliſters as big as wallnuts; which we "attributed to our coming too haſtily to the fire." And, therefore,

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fore, the proper method is, to waſh the frozen part in very cold water, or rub it well with ſnow, before the perſons thus affected enter a hot room. I wou'd willingly have tried the effects of different kinds of thawing upon frozen beef; but failed of an opportunity. An intelligent perſon who had lived in *Muſcovy* told me, that having two very large cheeſes frozen in that country, he thaw'd one of them in water, and the other in a ſtove; whereby the former became much the better of the two: he added that the cheeſe thaw'd in water, preſently acquired a cruſt of ice therein. PHYSICS.

12. *Hildanus*, in his treatiſe of gangrenes, tells us, "that a nobleman, "who had travell'd in the more northern regions, aſſured him, he there "once found a man upon the road ſtiff, and almoſt froze to death; "whom, having carried him to an inn, the maſter thereof preſently "plunged him into cold water, whereby his whole body was covered "over with ice; then having drank a glaſs of ſpiced hydromel, he was "put to bed, where he ſweat and recovered; but loſt the firſt joints of "his fingers and toes.

13. The experiments lately delivered, wherein ice was ſpeedily produced on the outſide of frozen eggs and apples, by immerſing them in cold water, ſeem very well fitted to diſcover the cauſes of congelation; but I ſhall not here build any hypotheſis upon them.

14. Whether bodies be froze by the admiſſion of frigorific atoms, that diſorder the texture of the frozen body, or the abſence of ſome matter that, before congelation, more ſtrongly agitated their parts, or in what other manner ſoever; 'tis manifeſt that the nature of the congealed ſubſtance is greatly alter'd from what it was before. 'Tis, therefore, proper to enquire how cold affects bodies, with regard to their preſervation and the deſtruction of their textures. But the nature of particular bodies, the different degrees of cold whereto they are expoſed, and the different times wherein the condition of each is examined, muſt here be carefully regarded: for we find that a moderate degree of this quality, preſerves many ſubſtances; and that glaciation deſtroys or prejudices ſeveral others: tho' while the froſt continues in them, it, almoſt univerſally, prevents putrefaction.

15. That a moderate degree of cold, conduces to preſerve the greateſt part of inanimate bodies, is generally acknowledged; nor, perhaps, does any degree of this quality below freezing, ſpoil what is expoſed thereto. "At *Modena*," ſays *Bartholin*, "they lay up ſnow in their re-"ſervatories, where I have ſeen them, during the heat of ſummer, long "preſerve the fleſh of animals from corruption." And Captain *James* relates, that "on the *9th* of *May*, he drew up from under water, five "barrels of beef and pork, four buts of beer, and one of cyder, where, "tho' they had lain all the winter, he found them never the worſe "for it." He mentions it alſo, as a remarkable thing, "that a cable,

"which

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PHYSICS. " which had lain buried in ice, during the whole winter, was found, up-
" on being thaw'd in *June*."

16. *Bartholine*, alſo, relates from *Sminlerus*, that "a large quantity of
" ſnow, falling from a part of the *Alps*, buried above ſixty *Switz* ſoldiers
" of the company that happened to be there, marching over them. In
" which caſes, the bodies lie till the beginning of the ſummer, when the
" ſnow, being ſomewhat diſſolved, they are found freſh and uncorrupted.
" And of this," adds he, " I my ſelf am an eye witneſs."

17. Many inſtances might be produced to ſhew that moſt inanimate bodies, while actually froze, will diſcover no putrefaction; and the thing it ſelf ſeems reaſonable: becauſe, whether the fluid parts are here wedged in by the intruding ſwarms of frigorific atoms, or whether thoſe reſtleſs particles that keep a body ſoft or fluid, are called forth by the cauſes of glaciation; there muſt be an unuſual reſt in the moveable parts of ſuch ſubſtances, as are either the cauſe or neceſſary attendants of corruption.

18. An ingenious man, who had made ſome ſtay upon the coaſts of *Sweden* and *Denmark*, told me, that dead bodies would, there, of themſelves, keep untainted during the froſty ſeaſon; that is, for three or four months together. *Bartholine* informs us, that the bodies of men, kill'd during the hard weather, remain ſtiff in the poſture wherein they expired. " After a great ſlaughter of the enemy," ſays he, " in the
" battle fought near our city, *Feb.* 11. 1659. the field was found ſtrew'd
" with ſtiff carcaſſes, ſome whereof ſhew'd anger in their faces, ſome
" had their eyes lifted upwards, and others ſeemed threatning a blow with
" their ſword; and all lay in different poſtures. And when, in the fol-
" lowing ſpring, it began to thaw, an entire man roſe up from the bot-
" tom of the ſea, (that had been frozen) ſitting on his horſe, and hold-
" ing ſomething in his hand." " Near ſix months," ſays Captain *James*,
" after our gunner was dead, and committed to the deep, at a conſidera-
" ble diſtance from the place we were now in, *May* 18. our maſter eſpied
" his corps in the ice under the gun-room ports; whence having dug him,
" we found his ſcent no more diſagreeable, than when firſt thrown over
" board; but his fleſh would ſlip up and down his bones, like a glove
" on a man's hand."

19. Some *Engliſh* relate, as we find in *Purchas*, of the *Samejeds*, " that they buried their dead on the ſides of the hills, and raiſed a
" pile of ſtones, ſo looſely over them, that the bodies appear thro';
" but the air is ſo piercing, that it keeps them from putrefaction."
The ſame author ſays, in the deſcription of *Iſleland*, " that the method
" of managing fiſh there, is, having firſt taken out their bones and
" bowels, to throw them on heaps in the open air; the purity
" whereof is ſuch, that they are thus hardned and preſerved bet-
" ter than by ſalt." The phyſician to the emperor of *Ruſſia*, told me, that dead bodies, if thoroughly frozen, wou'd with them continue uncorrupted

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ſon of elks, at *Moſcow*, untainted, tho' it came without ſalt, ſome hundred of leagues; and that all fleſh, when well frozen, would remain ſweet for a very long time; that, when kept congealed too long, it grew dry and inſipid, and would not afford ſo good broth as meat that had never been frozen; and that if leiſurely thaw'd, it receives far leſs damage, and will roaſt well; but if laid to the fire before 'twas uncongealed, it wou'd neither roaſt nor eat tolerably, but continue raw in the middle, tho' kept there turning ever ſo long upon the ſpit.

'Tis farther remarkable, what the merchants of *Copenhagen*, who trade to *Spitzberg*, in *Greenland*, relate, "that the extreme cold of thoſe parts, "will ſuffer nothing to putrefy or corrupt; ſo that corps there, continue "ſound and entire for thirty years after burial."

20. Whilſt bodies remain frozen, the cold, probably, by preventing that irregular motion and avolation of their particles, whence corruption proceeds, may keep its pernicious effects from appearing; but when once that impediment is removed, many ſubſtances immediately diſcover a diſcompoſure of their texture thereby occaſion'd, This, in ſome caſes, will be manifeſt to the ſight: thus by freezing an ox's eye, the cryſtalline humour loſes all its tranſparency, and appears perfectly white throughout. The perſon, alſo, who made the experiment with the two frozen cheeſes, obſerved both of them to be manifeſtly impaired by the cold; tho' one much leſs than the other.

21. "The *Dutch* ſailors likewiſe," ſays *Gerat de Veer*, "when they "winter'd in *Nova Zembla*, had their ſtrong beer ſo frozen, that they were "obliged to melt it for uſe; the ſpirituous part whereof being fluid, like "yeaſt, and too fiery to be drank alone, they mixed it with the diſſolved "ice, which neither then, nor before, had any ſtrength or taſte," And Captain *James* relates, that "having in his cold ſtation, reſerv'd "ſome *Alicant* wine, till the ſpring; when, mixing it with water, it "made but a very weak liquor; having loſt its virtue, by being "frozen."

The *Ruſſian* emperor's phyſician inform'd me, that when ſome very ſtrong *French* claret, that was frozen, came to be thaw'd, he found its colour tolerable, and the liquor very little impaired; that a weaker ſort, by this means, loſt its colour, and became much worſe; but that the third part of them remained uncongealed: whence the cold, whereto they were expoſed, appears to have been nothing near ſo violent as that experienced by the *Hollanders* and Captain *James*. The ſame phyſician, likewiſe, told me, that having a quantity of ſtrong beer, in great part frozen, he found the ice to retain ſome taſte of the hops, tho' it ſeemed diſpirited, like phlegm.

22. A

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PHYSICS. 22. A man of learning, told me, that in a *Northern* country, leſs cold than *Muſcovy*, he obſerved ſome beef, which, having been very long frozen, was almoſt inſipid when it afterwards came to be eaten; and that the broth it afforded was little better than common water.

23. I deſigned, but wanted opportunity, to try whether ſome particular plants and parts of the *Materia Medica*, with whoſe ſpecific virtues I was acquainted, would looſe their reſpective qualities by a thorough congelation, and different methods of thawing; as whether, for inſtance, thaw'd hart's-horn, the quantity and ſtrength of whoſe ſalt and ſaline ſpirit ſhould, before its freezing, be tried by diſtillation, wou'd, after having been long congealed, yield, by the ſame treatment, a like proportion of thoſe ſubſtances. We had, alſo, thoughts of making experiments with amber and load-ſtones, to ſee whether the moſt intenſe degree of cold, long continued, would affect the attractive faculty of the former, and the attractive and directive virtue of the latter.

24. Credible teſtimonies are not wanting to ſhew, that intenſe cold may have very conſiderable effects upon the texture, even of ſolid and durable bodies. 'Tis commonly allowed, that mens bones are more apt to break, by falls, in froſty weather, than at other times; and 'tis uſually found that the ſteel laths of croſs-bows, are render'd ſo brittle by cold, that more than ordinary care is required to prevent their ſnapping in the winter: and I am, alſo, inform'd by an ingenious overſeer of buildings, that thoſe who deal in timber, find it cleaves more eaſily in hard, than in open weather. But theſe effects of cold, are trifling to what may be met with in more intemperate regions.

25. Captain *James* ſays of the timber he uſed in *Charlton*-Iſland, "that "every piece was thaw'd in the fire, before the carpenter cou'd work it; "and that they were obliged to thaw the ſtanding trees, in the ſame "manner, before they could fell them."

26. Two different perſons alſo aſſured me, that in extreme froſty weather, they had obſerved the timber of the wooden houſes in *Muſcovy*, to crack with a loud and ſurprizing noiſe, but eſpecially in the night.

The above-mentioned phyſician told me, that the ſtones uſed for building in *Ruſſia*, were frequently reduced to duſt by the cold; and that he had often, in ſharp froſts, eſpecially if unattended with ſnow, heard, during the night, the trees cleave and crack with a frightful noiſe; that the out-ſide of the fir-trees, uſed in their buildings, ſometimes did the like; and that both of them would thence receive large gaping clefts, which continued till the thaw; when they would cloſe up again of themſelves.

27. And a phyſician, who lived for ſome years in one of the coldeſt plantations of the *Weſt-Indies*, aſſured me, he had found the bricks he employ'd in building, very apt to ſpoil by the long and vehement froſts

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exceſſive cold of the climate, that crumbles the bricks, and moulders them away. This may ſeem the more credible, ſuppoſing no defect in the bricks, if what a learned and credible author relates be true, as to the power which freezing cold had to break even ſolid marble. Nay, *Olaus Wormius* declares, that even braſs inſtruments have been broken by the cold. And to this we may add, that the *Dutch*, in their ſtay at *Nova Zembla*, found ſome of their beer barrels, with the iron hoops of others, frozen to pieces: tho' this effect was not, perhaps, immediately owing to the froſt, but the expanſion of the liquor in the veſſels.

28. General *Drummond* aſſures me, he has ſeen ponds frozen ſtrong enough to allow cannon to paſs over the ice thereof, while they yet contain'd plenty of live fiſh, which, if caught and packed up immediately, wou'd, of themſelves, continue ſweet for about a month. 'Twas remarkable here, that the fiſh, being drawn out of the water, and expoſed to the cold air, were immediately frozen as ſtiff as a board; when, ſaid he, if they had been thaw'd by a fire, that would have quite ſpoiled them: and fleſh, by the like treatment, becomes incredibly hard and tough; but both being kept in cold water, they will there thaw, become tender, and fit for dreſſing; tho' in thawing them, the General had not obſerved them to acquire a coat of ice. The ſame perſon farther told me, he had frequently ſeen men with their noſes and upper part of their cheeks frozen, while they themſelves were not aware of it: the remedy for this, he ſaid, was to rub the frozen parts with ſnow; a warm room, being carefully avoided before its application. In *Lapland*, it ſeems, they have another preſent remedy to reſtore frozen limbs, by anointing them with the fat of toaſted cheeſe made of deers milk. But the other is the general practice in *Ruſſia*, as I am inform'd by the phyſician to the Emperor of that country; and the Doctor told me he had diſcourſed with a man, who in his youth was frozen all over, by quitting his ſled, and uſing exerciſe 'till he almoſt ſweat; and then returning to the ſled again: and thus he might eaſily have died, had not the company accidentally obſerved his condition (for the perſon who is froze, ſeldom finds it himſelf) and rubbed him over with ſnow. He told the Doctor, that during the whole time of his being thus affected, he felt no pain; but as he recovered, perceived ſuch a kind of pricking as happens in a part benummed by leaning upon it.

29. 'Tis the cuſtom in *Ruſſia*, to thaw their frozen fiſh before they dreſs it, by letting it lie in cold water, 'till cover'd with ice, which having taken off, they lay it in other water, and again take off the ice; and this they repeat, 'till no more ice appears.

30. A phyſician of my acquaintance, having purchaſed ſome *Malaga* ſack at *Moſcow*, which was drawn from a frozen hogſhead of the ſame liquor, it proved much better and ſtronger than was expected; but the remaining part of the ice being thaw'd, was little more than phlegm.

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PHYSICS. The Doctor, alſo, obſerved, the like to happen in ſome other liquors: he did not, however, find that the ſpirituous part always retired to the center of the veſſel, but that it lay ſometimes interſperſed among the ice.

31. Some ſailors having left a barrel of ſtrong beer on ſhore in *Greenland*, found it at their return thither, the year following, very hard frozen; but running a heated ſpit into the middle of the ice, there iſſued out a turbid liquor, that was exceeding ſtrong and ſpirituous, whilſt the frozen part was almoſt inſipid.

32. General *Drummond* acquaints me, that the *French*, and ſometimes alſo the *Spaniſh* wines, yearly brought from *Archangel* to *Moſcow*, are ſo frozen at their arrival thither, that the owners are obliged to ſtave the caſks, cleave the ice with hatchets, and ſend it away in jars; and when this is deſign'd to be reduced to liquor again, they place it in another caſk, and bury it deep in ice or ſnow, where it gradually thaws, without receiving much damage.

X.

Experiments relating to the expanſion of water, and aqueous fluids in freezing.

1. That water and other fluids are condenſed by cold, in proportion to the degree wherein that quality affects them, has been generally allow'd; till ſome ſpeculative men of late, queſtion'd the truth hereof, upon account of the levity of ice, and maintained that body to be not condenſed, but rarified water.

2. And, indeed, if in our method of freezing water, from the bottom upwards, a bolt-head, fill'd till the fluid reaches into its ſtem, be employ'd, the ice will aſcend much higher than the water did before it was froze; and upon the gentle thaw of that ice, the fluid it turns to, will deſcend to the height it ſtood at, before its congelation began.

3. There are other ways to manifeſt the expanſion of water by freezing. Having poured a proper quantity of water into a ſtrong cylindrical earthen veſſel, we expoſed it, uncovered, both to the open air in froſty nights, and the operation of ſnow and ſalt; and obſerved that the ice produced in both caſes reached higher than the water before 'twas froze. And if a concave cylinder, made of any compact matter, be ſlightly ſtop'd at one end with wax, and filled with water at the other, and then that, alſo, be cloſed in the ſame manner; if, I ſay, this pipe be ſuſpended in air ſufficiently cold, the contain'd water will be froze, and the ſtopples at both ends, or at leaſt at one, will be thruſt out; and a rod of ice appear thereat, in continuation with the tube.

4. Having cauſed ſome large ſtrong bottles to be fill'd with a congealable liquor, (excepting their necks which contain'd ſallet oil,) I obſerved that, during a very long and ſharp froſt, the contain'd water was ſo far expanded by congelation, that it not only thruſt the corks, but the congealed oil, together with the frozen water, out of the necks; while

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while there appeared, above the upper part of the bottles, cylinders, ſeveral inches in height, conſiſting partly of concreted oil, and partly of congealed water, with the corks on their tops. PHYSICS.

5. But 'tis ſaid, in defence of the vulgar doctrine, that the cold of the external air, contracts what is contain'd in the glaſſes, when they break in froſty weather, and burſts the ſides thereof, to fill the ſpace deſerted by the ſhrinking of the internal fluid; for fear a vacuum ſhould be left in the glaſs. The preceeding experiments, however, may ſerve to ſhew the contrary: and tho' veſſels only half filled with water, are often burſt by this means; we have ſufficiently accounted for that phenomenon, without the help of a *Fuga vacui*, or the weight of the external air, by the bare expanſion of the contain'd liquor; the glaciation whereof begins, as we have formerly ſaid, at the top; where the ice firſt ſtrongly preſſes againſt the ſides of the glaſs: whence the water is preſſed between that and the bottom; and conſequently by its expanſive force in freezing, burſts the including veſſel, if it make not a proportionable reſiſtance. But farther, if water be frozen in a broad veſſel, that is too ſtrong to yield to the force of the froſt, the ſurface of the ice contiguous to the air, will riſe convex; the expanſive power of the fluid prevailing there more than againſt the ſides or bottom of the veſſel. And, laſtly, having carefully ſealed three very light and thin glaſs bubbles, of different ſhapes and ſizes, whilſt the air, within them, was of a convenient temper, we expoſed them ſometimes to very froſty weather, and at others, to a mixture of ſnow and ice; but could not perceive, that any of them were ſo much as crack'd thereby; ſo that if the included air was here, according to the popular notion condenſed, the ſpace it deſerted was a vacuum; whence conſequently the bubbles would have been broke.

6. Having filled ſeveral long vials to the lower part of their necks with common water, and left them all unſtopp'd; not only one of them that I ſtir'd up and down in a mixture of ice, ſalt, and water, was ſuddenly broken upon the congelation of the contained water; but many others that were expoſed to freeze more leiſurely in the air, were likewiſe broken to pieces by the expanſion of the freezing water; as appeared both by the gaping cracks, and becauſe the ice was conſiderably riſen in the necks, above the former ſtations of the water: and if it had been more eaſy for the included water to gain room, either by ſtretching the glaſs, or leaving the ſuperficial ice congealed, at firſt, in the neck, or by both theſe means together, than to break the vial, it would, probably, have remain'd entire.

7. Not only water, but other moiſt bodies expand by cold. When upon expoſing eggs to a ſufficient degree of this quality, the contained moiſture was turned to ice, it burſt the ſhells aſunder, and occaſioned many gaping cracks therein.

8. Milk, urine, and *Rheniſh* wine, being ſeverally expoſed in glaſs-eggs, to freeze, they were not obſerved to ſubſide before they roſe

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PHYSICS. the urine began to swell much later than the other two, tho', at length, it ascended much higher than they; the wine rose an inch above its mark, milk two, and the urine six or seven.

9. We poured a strong solution of *Dantzick* vitriol, into a cylindrical tube, sealed at one end, till it rose to the height of six or eight inches therein; then freezing it with snow and salt, the liquor became very opake, and appeared as if it had been wholly turned into vitriol, except a little that remained at the bottom, transparent and fluid; while the ice here rose considerably higher than the solution did before congelation. 'Twere worth trying whether even firm, solid bodies, would not dilate with a somewhat excessive cold. The invisible moisture in the air, before rainy weather happens, apparently alters the dimensions of doors, window-shuts; and such wooden work as has not been well seasoned. Much more water is used to make bread than what exhales in the oven, yet the remaining water is invisible; and thus, hart's-horn, spunge, and many other dry bodies, afford, by distillation, plenty of phlegm, which cannot be wholly attributed to the operation of the fire upon them. Such considerations make it probable, that the moisture actually existing in solid bodies, may dispose them to swell in freezing. This experiment, carefully made, might give light to the strange phenomenon, observed by the *Dutch* in *Nova Zembla*, where their clock, says *Gerat de Veer*, was so frozen by the cold, that an additional weight would not make it go. And the same thing is related by Captain *James*, to have happened both to his clock and watch; tho' they were constantly wrapped up, in a chest that stood by the fire side. This effect, indeed, might possibly proceed from other causes; but if, as we formerly observed, the frost can get into metals, it may also distend them; from whence, in this case, that correspondence between the parts of the clock, that is necessary to its motion, may be destroy'd: thus I have seen the exact parts of an iron instrument, would by no means fall in with each other, when expanded by heat.

10. Having almost filled a bolt-head, whose stem was purposely drawn very slender, with water, and placed it in a mixture of salt and ice, the water immediately appeared to be a very little depress'd; tho' it afterwards fell no lower, nor exhibited any other phenomena of freezing water, except that when the fluid began to congeal at the bottom, it had a manifestly quick ascent. We, therefore, caused the bolt-head to be made with its spherical cavity 3 ½ inches in diameter, and stem no thicker than a raven's quill; and filling this to a proper height with water, we observed upon immersing the glass in the same kind of mixture, that the water instantly ascended the length of a barley-corn in the stem, with the utmost velocity; after which, the water slowly subsided again to its former station: which agrees very well with the supposition of the *Florentine* virtuosi, who imagine so sudden a change must proceed from the contraction of the containing glass.

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preſs'd ſoon after its firſt ſubſiding, before it began to riſe; tho' I have formerly found water to ſuffer ſome degree of condenſation by the action of a frigorific mixture, before it began to yield any ice. We farther obſerved in this experiment, that after the ſinking, or immediately upon the firſt riſe of the water, the ſurface reſted a while in the ſame place, till the upper part of the water began to aſcend by reaſon of the glaciation of the lower; but this pauſe was very uncertain in its duration, according to the different ſtrength of the action of the mixture on the adjacent water. The fluid beginning to freeze here, roſe with a ſurprizing velocity up the ſtem; ſo that in the ſpace of a minute, it would often ſhoot to the height of ſeveral inches; and would, probably, have riſen much higher, if the ſtem had been of a ſufficient length. In all the repetitions of this experiment, I never ſaw any conſiderable intumeſcence of the water immediately precede glaciation; but the aſcent of the fluid was always attended with, if not preceded by the actual freezing of ſome parts of the water that lay neareſt the mixture: which I take to be the cauſe of this phenomenon. But ſo ſmall a degree of glaciation is required to make the fluid ſenſibly riſe, that it requires attentive eyes to diſcover it. Laſtly, we remarked with pleaſure, that if the glaſs in this experiment, were immediately taken out of the mixture, after the water began to aſcend; the very thin film of ice would be ſuddenly thaw'd hereby, and the liquor begin again to ſubſide in leſs than half a minute; but upon replacing it in the ice and ſalt, immediately after the diſſolution of the films of ice, the liquor began again to freeze in an inſtant: ſo that ice has ſhot up into the ſtem, in the ſpace of half a minute from its return; and within a minute and a half more the cavity of the ſpherical part has appeared filled therewith.

XI.

Experiments relating to the contraction of liquors by cold.

1. It muſt not be univerſally concluded from the preceding experiments, that all liquors will expand by any degree of cold whatever; for in our trials with ſpirit of wine, *Aqua fortis*, oil of turpentine, and other liquors, that we could not bring to freeze, the contrary appeared; as alſo in oil congealed by cold ſo that a great difference ought to be allowed between water and aqueous liquors on one ſide, and oil, and ſeveral other oleaginous, highly ſpirituous, or corroſive fluids on the other, as to the change of their dimenſions by cold. We have not, however, made a ſufficient number of experiments to reduce this matter to a certainty; but this, in the general, may be ſaid, we remember no ſenſible expanſion produced in any liquor, by cold, but rather a manifeſt condenſation, unleſs it were actually froze.

2. Upon ſurrounding ſpirit of wine, contained in a ſmall glaſs egg, furniſhed with a very ſlender ſtem, with a mixture of ice and ſalt, for ſeveral

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PHYSICS. ſeveral hours; it froze not at all, but gradually ſubſided, the length of ¼ inch in the ſtem; and tho' it afterwards ſeemed to riſe a little, yet it never, during that time, aſcended to its firſt ſtation.

3. Pouring mercury into a bolt-head, till it reached pretty far into the neck, which was purpoſely made more ſlender than ordinary, purging it of the air it contained, and placing it in a mixture of ice and ſalt; the cold affected it ſo much, that we diſcerned it to move downwards the length of two inches in the neck: which great deſcent cannot poſſibly be attributed to the contraction of any remaining air; tho' it had thereby been reduced to a point. We found, alſo, that the mercury, tho' not frozen by this means, retained part of its acquired cold, for many hours after; for it continued below its original ſtandard, tho' kept all night in a warm room.

4. We poured common oil into a ſmall glaſs-egg, with a ſlender ſtem, till it roſe conſiderably above the oval part of the glaſs; then placing a mark at the ſtation of the fluid, we ſet the veſſel in ſnow and ſalt; whereby it ſubſided, till it became quite congealed; when it appeared ſhrunk above an inch below the mark, whereto, upon being thaw'd, it re-aſcended.

5. This experiment was repeated with nearly the ſame ſucceſs; but we now found, that if the glaſs were removed from the mixture to any place near the fire, the oil not only thaw'd, but aſcended above the mark. For a third experiment, we ſealed up the oil in the ſame glaſs, which gave us ſtill the ſame phenomenon. That the congealed oil was here really condenſed, appeared from its ſinking in the ſame kind of oil cold and unfrozen; notwithſtanding the ſeveral bubbles of air that uſually adhered to each lump, wherewith we made the experiment. This was not only tried with oil, congealed by ſnow and ſalt, but with ſome leſs frozen by the bare cold of the open air; but the latter appeared to ſink more ſlowly than the former; and lumps of it would not continue under ſack, or claret, but if thruſt down herein, preſently emerged.

6. Whether chymical oils, tho' they alſo ſhrink with a moderate degree of cold, will contract or expand by freezing, we cannot determine; the higheſt degree of cold we could procure, proving inſufficient to congeal them: but ſurrounding a ſhort glaſs pipe full of liquid oil of aniſeeds, with ice, obtained in a warm ſeaſon, we obſerved, when it had hereby loſt its fluidity, 'twas conſiderably ſunk below its former height.

7. We alſo made the experiment with the empyreumatical oil of guaiacum, by expoſing it, in veſſels of a proper ſhape, to the greateſt degree of cold we could produce; but it did not thereby loſe its fluidity, only ſhrunk very manifeſtly.

8. We immerſed two ſealed weather-glaſſes, (filled the one with ſpirit of wine tinged with cochineal, the other with a blue mixture of the ſpirit of human blood, copper, and ſpirit of wine) in water, till it began to freeze; when removing the glaſſes into oil of turpentine, ſurrounded with

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with ſnow and ſalt, the liquors of both thermometers conſiderably ſub- PHYSICS.
ſided, and the blue one above half an inch; whence, by the way, it farther appears, that the air can impart a greater degree of cold than is required to freeze water, or than ice itſelf will always communicate.

9. Eſſential oil of aniſeed being poured into a round glaſs fitted with a ſtem, 'till it reſted at the height of five inches above the ball, we placed the glaſs in a veſſel of water made cold by ſal-armoniac; whereby, when the oil was coagulated, almoſt like *Sperma Ceti*, its upper ſurface, we found, had ſhrunk three inches below the mark it firſt ſtood at: and the oil, when thus congealed, notwithſtanding the many bubbles of air it then contain'd, wou'd ſink in water, tho' when liquid it floated thereon.

XII.

Experiments in conſort, relating to bubbles, the ſuppoſed cauſe of levity in ice.

1. What gave the moderns their firſt hint, to ſuſpect water to be expanded by freezing, was the floating of ice upon water; which is moſt viſible in large quantities of that concrete: for in ſmall fragments it will ſometimes riſe but very little above the ſurface of the fluid; tho' ſailors complain, that, in the frozen ſeas, they often meet with floating rocks of ice, as high as the maſts of their ſhips. Now, in caſe the ice be ſolid, and not compoſed of ſeveral fragments cemented together, ſo as to leave large cavities filled with air, 'twou'd be eaſy to determine *à priori* its height above the water; ſuppoſing circumſtances as they ſtand with us: for a priſm of ice floating, erect, in freſh water, wou'd, according to our experiments of the expanſion of water by freezing, have its immerſed part eight or nine times longer than its extant.

2. Pieces of clear ice, apparently free from bubbles, wou'd not, in our trials, ſink in ſpirit of wine, of the firſt diſtillation from brandy, and floated in that drawn from quick-lime; but if the ſpirit were well warm'd, 'twou'd ſink; and ſometimes ſlowly emerge, or remain ſuſpended, as the liquor grew cold again; whilſt the ice, thaw'd by the heat, ſtream'd viſibly thro' the lighter ſpirit: common water, however, tho' heated very hot, ſuſtain'd the fragments of ice put into it, which in oil of turpentine, or thrice rectified ſpirit of wine, ſunk like a ſtone.

3. That the levity of ice, compared with water, proceeds from the bubbles of included air, which cauſe it to poſſeſs more ſpace when congealed, than when fluid, is evident from its texture. But if this alone be the cauſe hereof, many minute bubbles, inviſible to the naked eye, muſt be contain'd in ice; for, altho' numerous bubbles are conſpicuous in ſome parcels hereof, and even render them whitiſh and untranſparent; yet others that were clear as cryſtal, have been obſerved to float on water. We, therefore, examin'd ſome of the latter ſort

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PHYSICS. ſort with an excellent microſcope; but cou'd not by this means diſcover a ſufficient number of bubbles to perſuade us, that theſe alone were the adequate cauſe of the levity of ice. One piece, in particular, appear'd quite deſtitute of bubbles, when view'd with this glaſs; yet, when plunged under water, it wou'd preſently emerge; while another, leſs clear, ſhew'd plenty of bubbles, ſome whereof were ſmall as pins heads, and others ſo exceeding minute, as to be almoſt inviſible, thro' the microſcope itſelf. It may be here remarked, what will preſently be proved, that the abſolute weight of ice, and the water that afforded it, are the ſame. Bubbles, however, muſt, doubtleſs, be part, if not the whole of the cauſe, of the levity and expanſion of ice; and therefore, their generation is one of the moſt conſiderable phenomena of cold: and to find out how thoſe cavities are produced, and if perfectly full, what ſubſtance they contain, is no trifling enquiry into the nature of this quality.

4. Mr. *Hobbs*, with ſome others, ſeems to think the expanſion of water by congelation, is cauſed by a freſh inſinuation of the external air, which conſtitutes the bubbles obſerved in ice. But then, how happens it, that when oil is frozen, the admiſſion of the air does not expand, but condenſe it? However, pouring water into a glaſs-egg, blown with a long ſtem, till 'twas almoſt fill'd thereby, we ſealed it hermetically to prevent any inſinuation of the air; when, expoſing it to congelation, the frozen water manifeſtly expanded, and ſwelled with numerous bubbles, which often gave it a whitiſh opacity. And, metalline veſſels, alſo, being fill'd with water, and carefully ſtop'd did not prevent congelation, but the cold expanded the liquor, and turn'd it to ice, with plenty of bubbles.

5. 'Tis very improbable, that bubbles ſhould be produced by the air contain'd in the glaſs, mixing with the water that was hermetically ſealed up, becauſe, if bubbles muſt cauſe the expanſion, how ſhall the water be at firſt expanded to reduce the air into bubbles? Beſides, 'tis certain, the air retains its ſtation above the water, and keeps together in one parcel; as we ſhall ſee hereafter. Moreover, ice and bubbles here uſually begin to appear from the bottom of the veſſel; in which caſe the air, a body ſo much lighter than water, cannot be ſuppoſed to force its way thro' it; eſpecially ſince it does not appear to deſcend in bubbles, as is uſual where air penetrates water. But where the veſſel is quite filled before 'tis ſtopped, no air can dive into the contain'd water, becauſe none is left to have that effect. And laſtly, if all the bubbles were made of real air, and fill'd therewith, it wou'd emerge upon thawing the ice; and a quantity thereof be obtainable, capable of filling the exceſs of ſpace poſſeſſed by water, when froze, above what it took up when fluid: which is contrary to our experiments made to that purpoſe. Upon trial, however, we find, that

that theſe bubbles contain but little air; not more, perhaps, than uſually lurks in the particles of fluids.

6. And that all of them are not filled with the air originally contain'd in the water, appears from the expanſion of the water, and the quantity of ſpace poſſeſs'd by the bubbles; which ſpace cannot be adequately filled with the latent air, unleſs the ſame parcel of matter cou'd really fill more ſpace at one time, than at another; which ſeems phyſically impoſſible. But the following experiments will give more light in this matter. (1.) Having kept fair water in an exhauſted receiver, till it afforded no more bubbles, we immediately removed it into ſnow and ſalt, where it continued for a conſiderable time, before it began to freeze, whilſt we obſerved it not to ſwell near ſo much as common water; and the ice was but thinly ſtored with bubbles; tho' a few very ſmall ones appeared therein, upon viewing it, placed between the vigorous flame of a candle and my eye. (2.) Part of this ſame ice, being gently thaw'd, and poured into a glaſs tube to freeze afreſh, it ſwelled conſiderably, and burſt the glaſs; the ice appearing opake with bubbles. (3.) We poured water into a ſmall glaſs-egg, till it roſe to the height of an inch within the ſtem, and then placed it in a tall cylindrical receiver; after a thorough exhauſtion whereof, during which, the water ſeem'd to boil very conſiderably, and for a long while together, we removed the glaſs-egg into a veſſel of ice and ſalt, and there ſuffer'd it to remain for twelve hours, that all the water, except what was in the neck, might be perfectly froze; at the end of which time, we found it to have riſen far above its original height: removing then the glaſs into the open air, we quietly ſuffer'd the ice to thaw, whilſt in the external part of the ice, near the ſides of the egg, we beheld plenty of bubbles; but when this was diſſolved, the reſt of the ice appear'd of a peculiar and unuſual texture, without any viſible bubbles, but almoſt reſembling a piece of froſted glaſs; the parts cauſing the aſperity, ſeeming very thick ſet: this ice, however, floated in the liquor into which the other was melted; and whilſt a lump hereof remain'd, about the bigneſs of a walnut, we conveyed the egg back to the receiver, which having exhauſted, a few bubbles, at length, appear'd in the water; each whereof was an hundred times leſs than one of thoſe, firſt taken notice of in the ſame. Some ſmall bubbles alſo here appear'd in the ice, which were not perceived before; but it did not diſſolve manifeſtly faſter *in vacuo*, than in the open air; but being, at length, wholly uncongealed, we took out the glaſs, and found the water had ſubſided to its original ſtandard, if not, rather, a very little below it. The expanſion of the ice was here conſiderable; for the water roſe 3 ½ inches in the ſtem, tho' the whole quantity employ'd, were but two ounces and a half.

7. We fill'd a ſmall cylindrical tube, cloſed at one end, with water, and thruſt it into a wide-mouth'd glaſs half fill'd with ice and

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PHYSICS. ſalt; then conveying all into a receiver, and pumping out the air, a great number of bubbles iſſued both from the upper and lower parts of the water; moſt of which broke into the receiver. Then finding the engine to continue ſtanch, and by the ſwelling of the higher part of the water, the under to be frozen, we let in the external air, removed the receiver before the mixture was half melted, and found the water in the cylinder, as high as that mixture had reached, turn'd to ice, wherein were ſome large conſpicuous bubbles, and ſmall ones enow to render it opake.

8. Upon pouring water into a glaſs-egg, till it roſe to a certain noted height in the neck, and ſetting it to freeze in a mixture of ice and ſalt, that reach'd within an inch of its upper ſurface, we obſerved the following particulars. (1.) The water did not ſenſibly ſubſide before it began to freeze. (2.) Within a quarter of an hour, it began to ſwell, and ſome of its parts that lay next the ſides and bottom of the glaſs were frozen. (3.) In the ſpace of an hour, from firſt expoſing the water to freeze, it roſe 4 $\frac{3}{5}$ inches above the mark; and before 'twas taken out, it had aſcended 5 $\frac{1}{4}$ inches higher than the ſame, tho' part of the water then remain'd unfrozen. (4.) The lower parts, only, of the water were congealed, and not its upper ſurface. (5.) No conſiderable bubbles, during this great elevation, appear'd in the unfrozen parts of the water; but the ice ſeem'd full of them; and ſeveral, towards the latter end of the experiment, were grown very large and differently figured, whilſt others ſhew'd leſs. (6.) Upon taking out the glaſs whilſt the water was at the higheſt, and pouring in oil till it roſe two inches above the former ſurface, we nimbly ſealed the glaſs, during which operation the water ſubſided a little; but replacing the glaſs in the mixture, the water ſoon regain'd its former height, whilſt the height of an inch and half of the ſealed glaſs was unpoſſeſs'd by the two liquors. (7.) In theſe circumſtances we carefully weigh'd the egg, firſt in air, and then in water, the better to diſcover if the glaſs ſhrunk; and whilſt it hung balanced in the latter, the ice thaw'd, and many bubbles, great and ſmall, aſcended, the former with a wrigling motion, and vaniſh'd at the top. (8.) As the ice thaw'd, the water and oil deſcended, till the whole was diſſolved; at which time we obſerved the ſcales to continue horizontal; and that the water was again ſubſided exactly to its original ſtandard, notwithſtanding ſo conſiderable an avolation of bubbles. (9.) Inverting the glaſs, we gently broke off its ſealed ſlender end, under water, part whereof being impell'd up, ſenſibly reduced the air at the oppoſite end within narrower bounds. (10.) The glaſs being again inverted and held ſtill, the water newly admitted, together with the former, and the oil, poſſeſs'd the ſame places with the water and oil before the glaſs was ſealed. (11.) Laſtly, upon throwing out the oil, and employing a little of the ſame water, occaſionally, we found the glaſs,

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glaſs, fill'd to its higheſt mark, weigh'd 4374 grains, but when fill'd to the loweſt mark 4152, and when quite empty, only 1032 grains; ſo that the water contain'd between the higheſt and the loweſt mark, and raiſed by glaciation, was about a fifteenth part of the whole, and wou'd probably have been more, had the whole been frozen. PHYSICS.

9. We poured water into a large glaſs-egg, till it reach'd an inch high in the ſtem; then expoſing it all night to a mixture of ſnow and ſalt, placed below the bottom of the ſtem, we found the water, about ten the next morning, riſen fifteen inches above the former height; the whole cylinder of water continuing fluid; then ſuffering the water to ſwell freely, it reach'd, within ſeven or eight hours time, to the top of the glaſs; ſo that a drop or two ran over; that is, it aſcended nineteen inches above the firſt mark; which ſcarce allowed us to ſeal up the end; but, afterwards, removing the veſſel into a warm place till next morning, and all the ice in the belly being thaw'd, the water ſubſided a little below its firſt ſtation, by reaſon of a little that was ſpilt in ſealing the glaſs: but here an accident hinder'd us from proſecuting the experiment farther.

10. Another glaſs, furniſh'd as the former, being placed to freeze in the ſame manner, its water roſe near an inch in leſs than an hour; when that in the ball and juncture of the neck was frozen into *laminæ*, which after an hour and quarter diſappear'd in the neck; but in the ball there ſeem'd a white ice; and the water aſcended in all 4 ½ inches. Abundance of ſmall bubbles now, perpetually, roſe thro' the neck, and continued to do ſo till the thaw was finiſh'd; the white ice appearing full of bubbles. Upon proſecuting the experiment farther, the water continued to aſcend till it had reached about eight inches above the firſt mark; when, drawing the top of the pipe into a very ſlender cylinder to be ſeal'd, we again placed the glaſs in the mixture, that the air heated by the lamp, might cool; whereupon the water ſwell'd till it began to run over at the orifice of the ſmall pipe, which we then immediately ſealed up; ſo that the whole glaſs appear'd full of water, except an inconſiderable quantity of rarified air contiguous to the ſeal'd end. The egg being now brought into a warm room, ſtood there all night, and part of the next morning, before the ice was quite diſſolved; after which, we found the water ſubſided to its original ſtation. Things ſtanding thus, we inverted the glaſs, and plunged its ſealed end under water, then broke it off, whereupon the external air forced ſo much water into the pipe, that the upper ſurface reach'd ſeven inches above the firſt mark, and left an inch and half of the ſtem unpoſſeſs'd, below where it began to grow exceeding ſlender, and, alſo, as much of that part as, by gueſs, amounted to a quarter of an inch; whence the bubbles that cauſed the water to ſwell, and appeared in the ice, were equal to 1 ¼ inch of air, which, conſequently, was, in great meaſure, generated by this proceſs, as well as ſeven inches ei-

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PHYSICS. ther of a *vacuum*, or ſome ſubtile ſubſtance, which for want of elaſticity cou'd not be air.

11. Upon breaking a ſeal'd glaſs, fitted as the former, under water, a cylinder of 10 ½ inches was impell'd into it, whilſt the mark whereat the ice had ſtood, was 11 ½ above the firſt.

12. In the bolt-head that ſhew'd us the greateſt condenſation of air, the water was by cold made to riſe almoſt a foot above its original ſtation; when the glaſs being ſealed, and the ice being permitted to thaw gently, the water ſunk back to the firſt mark; we then inverted the glaſs, and broke off its apex under water, whence an addition of above eleven inches of water was, with ſome noiſe and violence, driven into the tube; ſo that near ½ inch of air appeared to have been generated or ſeparated in the operation.

13. Having cauſed the water to ſwell about ten inches in the ſame veſſel, we ordered it as before, and found the additional quantity of water, to be, alſo, about ten inches.

14. We obſerved, not only in water, but other aqueous liquors, that the ice-bubbles were not filled with air; for having froze milk and urine, and ſuffered them to thaw, they ſeverally ſubſided near their original ſtations; when inverting the containing glaſſes, and breaking them under water, the milk and urine were manifeſtly impelled upwards, and the ſtems appeared to have acquired an addition of five or ſix inches of water.

15. Upon breaking, in like manner, a ſealed glaſs of claret-wine, that we found in part frozen, the water was preſſed up ½ inch; which could not have happened if the generated bubbles had been full of genuine air. All theſe experiments, however, only ſhew us, that theſe bubbles are not filled by air, but leaves us in the dark as to what it is that fills them.

XIII.

Experiments to meaſure the expanſion of liquors by cold.

1. We have employed two different methods to meaſure the expanſion of fluids; and firſt, by pouring a certain number of ſingle weighed ounces of water into a bolt-head, and marking the height whereto each of them roſe, till the ſtem of the glaſs was filled, and afterwards pouring ſome of them back again, we ſuffered the remainder to freeze from the bottom upwards; and found that the ice made from eighty two parts of water poſſeſſed the ſpace of ninety one and an eighth; whence the water expanded by cold, took up about a ninth part more ſpace than before congelation.

2. After the ſame manner, we found at another time, that fifty five parts of water ſtretched, by freezing into the ſpace of 60 ½; about ſix of the former parts remaining unfrozen: ſo that this experiment nearly agrees with the preceding.

3. The

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3. The other way we made uſe of was, to fill a cylindrical tube, ſealed at one end, to a certain height with water; which we marked on the outſide, then kept the glaſs erect, and froze the water upwards, whereby we have obſerved it to acquire greater dimenſions, by a tenth, in the form of ice, than when fluid; tho' ſmall varieties may often happen from the difference in the water applied in this experiment, and other circumſtances; and, accordingly, I once found a greater expanſion than the laſt mention'd.

4. Expoſing water to freeze in a very even cylindrical glaſs, we found it expanded about an eighth, or, at leaſt, a ninth part upon glaciation: this we obſerved, alſo, a ſecond time, and ſuppoſed the intumeſcence might have ſtill been greater, but that the freezing ſucceeded ill in the cylinder.

5. Sealing up a bolt-head, whoſe ſtem ſtood ſeventeen inches above the ſurface of the contained water, and placing it in our freezing mixture for eight or nine hours, the water aſcended above 15 ½ inches; when being left to it ſelf for an hour, the ſealed end of the glaſs was blown off, quite round, and the bottom burſt into many pieces; the whole body of the pipe remaining ſound.

6. We ſealed up ſome water that had been well purged of air by the air-pump, in a bolt-head, whoſe pipe roſe five inches above the upper ſurface of the fluid; then ſetting the glaſs in a frigorific mixture, it exhibited an ice very prettily figured, and without manifeſt bubbles; and in leſs than two hours time, the water was impelled up 4 ½ inches, that is a little above the baſis of the cone made in ſealing; when the glaſs burſting with a noiſe, the pipe remain'd entire, and a conſiderable part of the water appeared unfrozen under the ice, and the broken veſſel ſeemed to ſmoke: and here, as we conjectured, the air was compreſs'd into about a twentieth part of its former dimenſions.

7. The ſpherical part of a glaſs-egg, about three inches in diameter, being filled with water to the bottom of the ſtem, was carefully freed from air, ſealed and expoſed to freeze from the bottom upwards; when the water in the ball was frozen, and a ſmall part of that in the bottom of the ſtem, the remaining fluid reached above 8 ½ inches above the original ſtation; while the whole length of the ſtem was little more than 10 ½ inches. The ſame glaſs of water being afterwards ſealed up with air in it, and frozen, the ice reached not quite four inches above the original ſtation; tho' 'twas now as well frozen as before.

But theſe experiments ſeem to contradict the accounts given us, by thoſe who have ſailed in frozen ſeas, of huge floating mountains of ice, with their tops a ſurprizing height out of water, in compariſon of their immerſed part. The *Dutch* tell us of one they ſaw in their famous voyage to *Nova Zembla*, that reached ſixteen fathom above the ſurface of the water, and but thirty ſix below it.

They

PHYSICS. They have alſo theſe two more remarkable paſſages in their voyage. "And we ſaw," ſay they, "another great piece of ice lying faſt in the "ſea, as if it had been a tower; we rowed up to it, and caſting out our "lead, found that it reſted twenty fathom on the ground under water, "and twelve fathom above the ſurface. — By caſting out our lead we "found another piece of ice lye eighteen fathom deep, faſt at the bottom, "and ten fathom high above the ſurface of the ſea."

And *Janus Munckius* mentions ſome floating pieces of ice, ſeen in his voyage to *Greenland*, that were extant twenty fathom, whilſt what remain'd of them under water was but forty; whereas, according to our computation, the immerſed part of ice ought to be eight or nine times as deep as its extent is high. To obviate this objection, let it be obſerved, that in our computation, the ice is ſuppoſed to float in freſh water, when, in the other caſe, it ſwims in the ſea, whoſe water is much heavier. We muſt, however, allow, that the ſea is leſs ſalt near the poles, than in the temperate or torrid zone; but then this leſſer degree of ſaltneſs may be ballanced by a greater degree of coldneſs, which vehemently condenſes that water, before it begins to freeze. However, the principal thing to be here conſidered is, that theſe prodigious maſſes of ice, are not uniformly ſolid, but compoſed of ſeveral rude portions cemented together, with huge cavities between them: and, according to *Bartholine*, chiefly conſiſt of frozen ſnow; ſo that their weight muſt not be eſtimated by their bulk, without allowing for the air and interſperſed vacuities in them; whence the whole icy mountain may preſs the ſubjacent fluid no more than a bulk of the ſame water equal to that of the immerſed part of the ice. Moreover, 'tis very probable, that theſe mountains of ice would ſink lower, had they a ſufficient depth of water; for I find not that any pieces have been meaſured that floated freely in the ſea; and therefore if their bottoms reſt upon the ground, the great ſnows, frequent in gelid climates, may eaſily fall upon their heads, and running together by the ſun's heat, *&c.* add to their height above water. Thus the ice obſerved by Captain *James*, to be twice the height of his top-maſt head, reſted in forty fathom water; and the large mountain above mention'd, obſerved by the *Hollanders* in *Nova Zembla*, lay faſt in the ground. But Mr. *Hudſon*, in the bay that has receiv'd his name, met with ſeveral iſlands of ice a-ground in ſix or ſeven ſcore fathom water; where, if the ſea had been deeper, they wou'd, doubtleſs, have ſunk lower, and ſo leſſened the height of their extant parts.

As no liquors have hitherto appeared to me expanded by cold, without actual freezing, 'tis a queſtion whether aqueous fluids expand by congelation upon any other account than that of the phlegm they contain: farther experiments might, however, be made to ſettle this matter.

1. The

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1. The force wherewith water expands in freezing, is greater than men generally imagine. We filled a half pint pewter bottle quite full of water, ſcrewed on its ſtopple, and expoſed it to the cold air of a froſty night, and by next morning found the water had burſt the bottle, which was new; the crack appearing in the very ſubſtance of the pewter. This experiment we repeated with the like ſucceſs. *Experiments to diſcover the expanſive force of freezing water.*

2. To try whether a ſmall quantity of water would produce the ſame effect, we poured about an ounce of water into a new ſmall and thick pewter pot; and found it conſtantly torn by the expanſive force of the ice.

3. We, afterwards, filled a quart bottle with a congealable liquor, and tied down the cork very firmly with ſtrong packthread; but notwithſtanding this precaution, the expanding fluid forced it out.

4. We, therefore, faſtened a cork ſtill more ſtrongly in the mouth of a quart glaſs bottle of water, which we expoſed to an exceeding ſharp air, for ſeveral hours, till, at length, the bottle burſt; tho' the thineſt part where it broke meaſured $\frac{1}{16}$ inch. In the ſame manner, we, alſo, broke a ſtrong earthen *Flanders* bottle, the thineſt part whereof meaſured, alſo, $\frac{1}{16}$ inch.

5. But to bring this force nearer to a computation, I made uſe of a ſtrong concave braſs cylinder, open at one end, which was exactly fitted with a cover, that, by its rim, fill'd up the mouth. This cylinder, which was five inches deep on the inſide, and 1 $\frac{1}{4}$ inch in diameter, we filled perfectly full with water, carefully placed on the cover, faſtened it into an iron frame that held it erect, and placed a ſmall half hundred weight thereon, and thus expoſed it to the cold air of a froſty night; but the contained water was found uncongealed, the next morning: and no better ſucceſs had we upon a ſecond attempt, whatever were the cauſe hereof. We, therefore, applied to the outſide of the veſſel, a mixture of ice and ſalt; yet, even by this means, the glaciation proceeded very ſlowly: but at length ice on one ſide ſwell'd above the top of the cylinder, there raiſed up the cover, and threw down the weight. At another time, however, we found both the cover and weight, uniformly lifted up to a ſmall height by the expanded ice. And here we took particular notice, that the included cylinder of ice being, after a gentle thaw of its ſuperficial parts, taken out, appeared opake with bubbles; and when the weight was newly taken off, there iſſued from a little hole, that ſeemed to be between the ice and edge of the braſs, many drops of water dilated into numerous bubbles, and reduced into a kind of froth, as if they had got liberty to expand themſelves by the removal of the weight: however, this phenomenon was but of ſhort continuance.

6. But

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6. But the inconveniencies attending this method, obliged us to alter the braſs cover for a well ſoak'd wooden plug, which, being forcibly driven into the mouth of our cylinder, could not be forced out by the weight of ſeventy five pound, hung thereto, while the cylinder was inverted. Water being thus expoſed to freeze, in a very ſharp night, thruſt out the plug about the breadth of a barley corn, quite round, above the upper edge of the cylinder; but continuing to freeze for two days longer, it, at length, forced it out near a quarter of an inch. How much greater the expanſive force of freezing water may be, we could not determine for want of convenient inſtruments wherewith to meaſure it; but this degree ſeems very extraordinary, conſidering water, when unconfin'd, extends it ſelf, by congelation, no farther than to poſſeſs, at moſt, an eighth more ſpace than when in its natural ſtate.

7. We took a ſtrong cylinder of braſs, its cavity two inches in diameter, and placed therein a well-tied bladder, including ſome water, which could not expand any way but upwards; to the mouth of this cylinder we fitted a wooden plug, to riſe and fall therein with eaſe; upon which we laid weights, to hinder its elevation when the water began to freeze; then applying ſalt and ice to the veſſel, the water in the bladder ſoon began to expand it ſelf, and, in two hours after, the plug appeared to be raiſed near half an inch, notwithſtanding the hundred and twenty pound weight that lay thereon. Upon repeating this experiment, inſtead of the forementioned weight, two hundred and fifty four pounds were now elevated by the expanſive force of the ice.

8. A gun-barrel, fourteen inches long, whoſe bore was in diameter $\frac{1}{4}$ inch, and where leaſt thick of metal $\frac{1}{4}$ inch, being filled with water, exactly cloſed at the breech, and ſtopped a ſcrew at the mouth, was buried in ice and ſalt for about two hours, and, during that time, received a crack of ſix inches long, that run obliquely from three inches above the breech, and appeared wideſt in the middle; where, alſo, the barrel ſeemed diſtended. The ice we thought contained ſmaller bubbles than if the water had not been pent up; but the ſmalleſt were ſo numerous as to hinder its tranſparency.

9. The touch-hole of a ſtrong gun-barrel, twenty four inches long, being ſtopped, and a plug of iron forcibly driven into the muzzel after the barrel had been filled with water, we placed it in a mixture of ice and ſalt, where, within about three minutes, the plug was, with a noiſe forcibly driven out of the mouth; and being now wedg'd and fixed in faſter than before, it was, in three minutes time, again forced out with ſuch a vehemence, that it broke a deal board of the box wherein the experiment was made. We afterwards incorporated the plug, by means of the fire and a hammer, with the muzzel of the gun; when expoſing it to freeze afreſh, the touch-hole gave way; and this cauſed

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the nail in, ſo that the water could not expand without burſting the barrel; and accordingly, within a quarter of an hour after it was thus placed in the freezing mixture, it burſt, with a loud noiſe, and blew up the cover of the box wherein it lay; tho' the crack which was 2½ inches long, diſcovered a very conſiderable thickneſs in that part of the metal.

10. A new pint, pewter bottle, filled with water, and a top ſcrewed on to it, being ſet in a frigorific mixture, for a quarter of an hour, it broke, with a noiſe, and exhibited a crack almoſt 1½ inch long, and in one place ⅛ inch wide. The bottle ſeemed to be every way diſtended, but particularly at the bottom.

11. I cauſed a ſmith to take a piſtol-barrel about two feet in length, and of a proportionable bore, and, by rivetting in a piece of iron, to ſtop exactly the touch-hole, and then fit to the mouth of the barrel a ſcrew, to go as cloſe as poſſible: this barrel being filled to the top with water; I cauſed the ſcrew to be very forcibly driven in, that the water, dilated by congelation, might neither preſs it out nor get between it and the top of the barrel; and having then ſuſpended the barrel in a perpendicular poſture in the free air of a very cold night, I found, the next morning, that the water had thruſt out a great part of the ſcrew, tho' I had oil'd it before, and was got betwixt the remaining part of it and the barrel; wherefore, the exceſſive cold continuing one day longer, I, the next night, cauſed the intervals that might be left betwixt the male and female ſcrew, to be filled up with melted bees wax; and having, in other points, proceeded as before, I found, the next morning, the ſcrew held as I deſired; and that the cold had ſo forcibly congealed and expanded the water, that it burſt the iron barrel near the top, and made a conſiderable oblique crack therein, about which a pretty quantity of ice appeared to ſtick, and alſo three or four other flaws or actual cracks, at ſome of which, ſmaller quantities of water appeared to have got out. When, by thawing one part of the ice, ſome pieces of the reſt were got out of the barrel, all I took notice of appeared to be full of bubbles ſmaller than ordinary.

12. Moreover, we attempted to freeze water that filled a ſmall cavity left in a thick iron ball, and cut into a female ſcrew, whereto a male one was fitted, to be driven by means of a vice; but any degree of cold we could procure proving unable, or not ſufficiently durable to congeal the water, thro' ſuch a thickneſs of metal, we cannot ſay what phenomena ſuch an experiment, ſucceſsfully tried, might afford.

13. But whence can this prodigious force of congealed water proceed? Should cold be, as the *Carteſians* would have it, only a privation

PHYSICS. of heat, or freezing be occaſioned, according to the *Epicureans*, by the entrance of frigorific particles; 'tis not very eaſy to account for this phenomenon. The firſt hypotheſis ſhews no cauſe of this expanſive power; nor does the ſecond explain how the admitted corpuſcles ſhould produce ſo ſtrange an effect, without giving any manifeſt ſigns of violence in their firſt admittance, when they freely penetrate the ſides of the veſſel they afterwards burſt. Beſides, in oil, which requires a great degree of cold to reduce it to a moderate hardneſs, the frigorific particles it admitted, do not expand, but contract it.

14. I leave it to others to make further experiments upon other aqueous liquors, as to their different degrees of expanſion by cold; I am told, however, that in *Ruſſia*, glaſs and ſtone bottles are frequently burſt by the congealed beer or wine they contain.

XV.

Experiments relating to a new method of eſtimating the expanſive force of congelation, and of highly compreſſing air without engines.

1. We poured water into a large glaſs-egg, with a proportionable cylindrical ſtem, till it aſcended about a finger's breadth into its neck, and then ſet it to freeze, for ſome hours, in ſnow and ſalt, with the top of the tube open, whereby the water roſe almoſt ſeven inches. At this time we nimbly ſealed up the upper end of the tube, that was drawn out exceeding ſlender, and ſuffered it to continue in the mixture, adding freſh ſnow occaſionally, for about twenty-four hours, to ſee how much the impriſoned air would be compreſs'd; which, at the time of ſealing, was a cylinder of about 9 ¼ inches high. This ſpace the upper water gradually invaded, as ice increaſed below, till, at length, the water reached almoſt 8 ¼ above the ſtation it had when firſt the glaſs was ſealed; and, conſequently, had crowded the air into the ſpace of about an inch. Then gently inverting the glaſs, that the air might come at the ice, for the water in the ſtem had purpoſely been kept fluid, we broke the ſealed end into a jar, whereupon the compreſs'd air immediately, and with violence, blew out of the tube, about ten inches height of water, that is a greater ſpace than was poſſeſſed by the air before condenſation: and ſuch a great multitude of bubbles were now ſet at liberty, that they roſe from the lower part of the glaſs to the top of the remaining water, as in bottled beer upon taking out the cork. 'Twas here remarkable, that when the air ſtood compreſs'd to ſeven inches, the middle of the glaſs poſſeſſed thereby, and neareſt to the water, was all around, to a conſiderable height, full of very ſmall drops like dew, which diſappear'd when we came to break the ſealed end.

2. Having fill'd a ſingle vial, with water, about half an inch above the lower part of the neck, and left two inches height of air in the remaining part thereof, which was, alſo, drawn out into a ſlender pipe, we ſealed it up, after the air had been thoroughly cooled, and ſet the water to freeze; whereby the air was condenſed into a leſs ſpace: but ſoon after, the upper part and ſlender pipe of the glaſs, were

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deed, was made of brittle metal; and the like accident also befel us in two other attempts.

3. We took a glaſs, in ſhape and magnitude like a turkey's egg, with a cylindrical ſtem, except that it was a little wider at the bottom than at the top, and filled it with water till only 4 ¼ inches of the tube remained empty; the upper part whereof was drawn conical, for the conveniency of ſealing: along this tube from the ſurface of the water to the top of the glaſs, we paſted a long ſlip of paper, divided into inches and quarters; then ſealing the glaſs, we obſerved, that by holding it in a warm hand, in a room where there was a large fire, the water roſe near ¼ inch; but placing the glaſs among pieces of ſolid ice and ſalt, the water preſently began to ſubſide, and, freezing ſoon after, to ſwell, ſo that by degrees it compreſſed the air into above a ſeventeenth part of the ſpace it before poſſeſs'd; till at length, the force of expanſion growing too ſtrong for the reſiſtance of the glaſs, it burſt, with a very loud noiſe, in its oval part; the pipe and ſeal'd end remaining entire; and the ice appearing full of bubbles, which render'd it opake and white. The water that had aſcended into the neck, was all driven out upon the burſting of the glaſs.

4. But the moſt ſucceſsful experiment of this kind, was made in a ſhort, ſtrong, glaſs-egg, whoſe ball bore a very large proportion to its ſtem; whence the expanſion might exert itſelf more forcibly. This veſſel furniſh'd with water, we ſealed exactly, placed a divided liſt of paper along its ſtem, and expoſed it to freeze in ice and ſalt, by which means the water preſently began to condenſe the air, aſcending, for a conſiderable time, very faſt, till it had crowded the contain'd air into a nineteenth part of the ſpace it at firſt poſſeſs'd; when preſently the ball of the glaſs was burſt to pieces, with a loud report; but the ſtem was left entire.

5. We took a round ball of glaſs, furniſh'd with a moderately long pipe, and having fill'd it with water, till the liquor reach'd within ſome inches of the top, we ſeal'd it hermetically; and then the water, by a mixture of ice and ſalt, was made to freeze from the bottom upwards; that, without breaking the glaſs, the unfrozen water might be impelled upwards by the expanſive endeavour of that which was freezing, and ſo, at once, both compreſs the air, and be preſs'd upon by it: having, by this means, condenſed the air, as far as we thought ſafe in the glaſs, we broke off its ſmall apex; when immediately the compreſs'd air flew out with a great noiſe, and part of the pipe, which was unfill'd with water, appear'd fill'd with ſmoke, that made it look white; and great ſtore of little bubbles haſtily aſcended from the lower parts of the water to the upper, where moſt of them quickly broke. But, what is principally to be noted, the water itſelf immediately aſcended ¼ of an inch. Tho' I am not ſure, till farther trial, that there was no ſpringineſs in the ice that contributed to the effect; or that

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PHYSICS. the great preſſure of the cõndens'd air, did not make the glaſs itſelf ſtretch or yield; in which caſe the parts of the diſtended glaſs, upon the removal of the forcible preſſure of the air, returning to their former ſtreightneſs below, will make the water aſcend ſomewhat higher in the pipe. But I cou'd not procure proper glaſſes wherewith to examine the truth of this ſuſpicion; which I wou'd, likewiſe, have tried by the bulk of the glaſs in water, before and after letting out of the compreſs'd air. But as four or five other trials made with another liquor, as well as water, exhibited a manifeſt intumeſcence; ſo in the preſent experiment, if we had judg'd our glaſs ſtrong enough to endure ſuch a compreſſion of the included air, as we have often employ'd on other occaſions, the effect wou'd, probably, have been much more conſiderable. For, tho' the difference between the length of the ſame water, compreſs'd and uncompreſs'd, amounted to a cylinder of $\frac{1}{8}$ inch in height, yet the air that made this compreſſion was itſelf reduc'd, but from eight inches to five; whereas we have ſometimes reduc'd it to an eighteenth or twentieth part of its uſual ſpace. I might add, that, when we broke off the ſeal'd apex of the glaſs, before the included air was much compreſs'd, there wou'd be neither any great noiſe made, nor any conſiderable froth produced at the top of the water; and that having repeated the experiment in one of the ſame glaſſes, and with the ſame water that had been already compreſs'd therein, we found, upon breaking off the hermetical ſeal a ſecond time, the water did, nevertheleſs, aſcend into the pipe, betwixt $\frac{1}{8}$ and $\frac{1}{4}$ inch.

6. This method of compreſſing air in veſſels hermetically ſealed, ſeems leſs exceptionable than any hitherto put in practice; and had we not wanted freezing materials, and proper glaſſes, I make no queſtion, but, we ſhou'd have reduc'd that fluid into a much leſs ſpace. And, by the way, this ſeems a promiſing method, wherein to attempt the compreſſion of water; for its having been hitherto found incompreſſible, may, perhaps, be owing to the poroſity of the veſſels employ'd, which admit the particles of the fluid to paſs thro' them, upon the ſudden application of any great force; whilſt, in our way, the force is gradually and uniformly exerted, upon the water, in a veſſel that may break indeed, but till then, remains perfectly impervious to the fineſt parts of the contain'd fluid. And in one of the preceding experiments, it appear'd, from the vaſt multitude of bubbles that manifeſted themſelves, upon the breaking of the glaſs, that the water which lay between the ice and the crowded air, had been violently compreſs'd by them; which we the rather believe, becauſe, having at another time, ſealed up ſome air and water in a glaſs-egg, and permitted the water to ſwell by the operation of the cold, till it had reduced the air into $\frac{1}{4}$ of its natural ſpace, we actually perceiv'd the water

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of the glaſs.

XVI.

Experiments and obſervations upon the ſphere of activity of cold.

1. 'Tis more difficult, than one at firſt ſight wou'd imagine, to determine the ſphere of the activity of cold; for to aſſign the preciſe limits wherein a cold body can operate, many particulars muſt be taken into conſideration: as, for inſtance, the degree of cold belonging to the given body; the medium thro' which its power is diffuſed; the conſiſtence, texture, motion, or reſt of that medium; the manner wherein the cold is ſpread, with regard to the inſtrument that acquaints us with it; the bulk of the body, *&c.* However, in the ſmall portions of ice employ'd in our experiments, we found the ſphere of activity very narrow; not only when compared to that of heat or fire, but the atmoſpheres of ſcented bodies, or even of the attraction in a load-ſtone: ſo that I have made it a queſtion, whether a cold body be diſcernable by us without immediate contact. And agreeable hereto, I cou'd not find, if a man's eyes were cloſe ſhut, that he was ſenſible of the neareſt poſſible approach of a tolerably large piece of ice, to the ends of his fingers.

2. And for farther ſatisfaction herein, I placed one of the moſt ſenſible thermometers very near to little maſſes of ſnow, but it took no notice of them, till we cauſed them to touch the inſtrument. This languidneſs in the operation may, however chance to proceed from the ſmallneſs of the pieces of ice employ'd; for a merchant, who has made ſeveral obſervations upon cold in *Greenland*, informs me, that upon the ſea they were apprized of their approach to ice, as well by the increaſe of cold, as the ſhining light it yields. Tho' this account, I muſt own, ſeems not to agree with that of ſome others, who have ſail'd in frozen climates; and once, in particular, I remember it is ſaid by ſome of them, that their ſhip lay aſide of vaſt ſhoals of ice, whilſt they, thro' fogs, remain'd ignorant of it. Tho' I have been inform'd by an old ſea captain, that when the wind blew from the great banks and tracts of ice, they felt an extraordinary degree of cold, ſometimes for twenty leagues before they came up to it.

3. We deſign'd to have tried, whether ſnow or ice wou'd freeze water, that was immediately contiguous to them; for *Olearius* relates, that at *Iſpahan*, the capital city of *Perſia*, where the water ſeldom freezes above an inch thick, and the ice preſently diſſolves upon the riſing of the ſun, there are ſtore-houſes furniſh'd with thick pieces of ſolid ice, procured by pouring a large quantity of water, at proper intervals, over-night, upon a ſhelving marble floor, where, as the water runs, it is frozen by the contiguous ice; which thereby, in two or three ſucceſſive nights, becomes conſiderably thick.

4. Once

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4. Once indeed, we attempted to make this experiment in *England*, when the water, inſtead of freezing upon the ice, diſſolved it; but then the water was freſh'd pump'd, and had not been ſuffer'd to cool in the open air, before we employ'd it; and therefore ſeem'd warmiſh in compariſon of ice. And indeed, allowance muſt be made for the different temperature of the air of different countries: for tho' water poured upon ſnow, is apt to diſſolve it with us; yet in *Ruſſia*, I am inform'd, they frequently convert water and ſnow into ice, by mixing them together.

5. Natural glaciation, uſually proceeds from the upper parts of bodies to their lower; but how deep the froſt will reach in earth and water, is not eaſily known; becauſe this depth may vary with the degree of coldneſs in the air, which appears to be the cauſe of glaciation, as alſo by a longer or ſhorter duration of the froſt, the texture of the earth, the nature of the juices wherewith it is impregnated, the conſtitution of its more internal parts, as to heat and cold, the nature of its effluvia, *&c.* Thus, I have ſeen a large tract of land, with vaſt quantities of lime-ſtones near its ſurface, where I was aſſured, that ſnow will never lye. And to try the depth, whereto froſt will penetrate into the earth, I made the following obſervation in a village near two miles from a great city. (1.) *Jan.* 22. After four nights of hard froſt, we dug in an orchard where the ground was level and bare, and found the froſt had ſcarce reach'd $3\frac{1}{4}$ inches; and in a garden, nearer the houſe, only two inches below the ſurface. (2.) Nine or ten ſucceſſive froſty nights, froze the bare ground in the garden $6\frac{1}{2}$ inches deep, and in the orchard, where a wall ſhelter'd it from the ſouth-ſun, to the depth of $8\frac{1}{2}$ inches. (3.) *Feb.* 9. We dug in an orchard near a wall, and found the froſt to have penetrated the ground about fourteen inches; when eight days before it was obſerved to be $8\frac{1}{2}$ inches. (4.) A ſlender glaſs pipe, eighteen inches long, ſealed at one end, and filled with water, being thruſt, over night, into a hole made in the earth, till the ſurface of the water lay level with that of the ground, the water appear'd, next morning, frozen in the cylinder only a little more than to the depth of three inches; but there reached downwards from this ice, part of a cylinder of the ſame, to the length of ſix inches; the reſt of the water remaining unfrozen, tho' in an exceeding ſharp night, and in a very hard ſeaſon. The earth in the garden where this experiment was made, ſeem'd frozen to the depth of eight or ten inches. (5.) Upon enquiry, I find, that in the moſt frozen countries, a congealing degree of cold penetrates the earth and ſea, nothing near ſo deep as is uſually imagin'd. A traveller aſſured me, that in a garden at *Moſcow*, he found the ground, in a hard ſeaſon, to be frozen, but little above two feet below the ſurface; and the utmoſt effect that Capt. *James* mentions the cold to have had upon the ground in *Charlton* iſland, was to freeze it ten feet deep: whence may appear

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as to the freezing of the water there, he tells us, "it does not natu-
" rally congeal above the depth of six feet, the rest being by accident;
" tho' ice may be seen here six fathom thick: this we found by dig-
" ging the ice out of our ship; and by digging to our anchor before
" the ice broke up." The same Gentleman also observed, that the salt water was not here much above half so thick frozen as the earth: but fresh water has a much greater dispostion to freeze, than that of the sea.

XVII.

1. In examining whether cold may be propagated thro' all mediums, universally, regard must be had to the particular medium wherein the experiment is made; for if it have too great a thickness, we may mistake by imputing to the nature of the medium, what is really owing to the distance, between the agent and patient. Thus mixtures of ice and snow will operate only at a very small distance, tho' the medium resist no more than common air. *Experiments upon the different mediums, thro' which cold may be diffused.*

2. Upon placing a large quantity of the mixtures of ice and snow in pipkins glazed within-side, and in white basons, glazed both within and without; the external surfaces of both were crusted over with ice, tho' the thickness alone of the vessels seem'd to be the utmost limits of the freezing power.

3. By the experiments formerly mention'd, as to freezing water in pewter vessels, it appears, that cold is able to operate thro' them.

4. This receives farther confirmation, from the making of drinking cups of ice; the method whereof is, to take a cup made of plated iron, and tinn'd over on both sides, of any assignable size; and of the same materials, a less of the same figure to go within-side the former, so as to leave a competent space betwixt the whole internal surface of the larger, and external one of the smaller; the latter cup hanging free, by its rim upon the edge of the former, and at a considerable distance from its bottom. The interval between the two cups being fill'd with water, and the cavity of the internal one with a mixture of ice and salt, and the external surface surrounded with the same mixture, the water is hereby quickly frozen; when, the parts of the mould being disjoin'd, the icy cup is made. To prevent the ice from adhering to the mould, we sometimes anointed the latter with some unctuous material; but the best way we found, tho' it made the cup less durable, was to thaw its surfaces, gently, by heat.

5. *Bartholine* mentions an experiment to turn air, as he calls it, into water, in a hot season; by placing some snow or ice in a funnel, to condense the watery particles, floating in the air, and cause it to trickle down the sides thereof. However, upon trial with large and thick glass funnels, containing a mixture of ice and salt, we were able

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PHYSICS. able to obtain only an inconſiderable quantity of water, which diſtilled from the ice, formed on the outſide of the glaſs, only whilſt the mixture was diſſolving.

6. That a mixture of ſnow and ſalt, included in glaſſes hermetically ſealed, condenſes the vapour of the air on the outſide thereof, we have already ſeen; from whence 'tis manifeſt, that the compact body of glaſs is pervious to cold: nor can the air be here ſuppoſed the medium that conveys it; however, we thought it proper to try, whether cold be convey'd thro' a *vacuum*, as 'tis uſually call'd.

7. A ſmall tube, ſealed at one end, and almoſt fill'd with water, being put into a convenient receiver, which we, firſt thoroughly exhauſted by the air-pump, and then ſurrounded with a mixture of ice and ſalt, to the height whereat the water ſtood in the ſmall pipe, that water was, at length, tho' ſlowly, frozen from the top to the bottom, into odd kind of flakes, without any conſiderable number of bubbles appearing therein.

8. That cold will act thro' a medium ſenſibly and continually hot, appears from drinking a large quantity of cold water; which will manifeſt its chillineſs thro' the integuments of the abdomen; as I have obſerved in myſelf upon drinking the mineral waters of *Tunbridge*: and this was, in a vehement degree, experienced by a gentleman, who drank them in a larger quantity at the ſame time.

9. Having with water fill'd a glaſs bubble, whoſe magnitude equall'd that of a walnut, its figure reſembling that of a pear, and whoſe ſtem was crooked; we ſuſpended it by a thread, the upper end whereof paſs'd thro' a ſlit in a cork, and was there faſten'd, in a wide-mouthed glaſs filled with common oil of turpentine, and cover'd with ice and ſalt, and cloſed with the cork: thus we left all for three hours; at the end of which time, tho' the oil remain'd fluid, the water in the bubble was wholly frozen, and the bubble itſelf crack'd ſo, that only a ſmall part of it came up with the thread; the ice wherein appear'd deeply cleft from the ſurface towards the centre, into two pieces eaſily ſeparable; as if a pear had been cut along from its ſtalk thro' the core: and leaving them in the ſame fluid and veſſel, with ſome thawing ice and ſalt about it, for fourteen or fifteen hours, they were not conſiderably waſted. And, by the way, along with this bubble, we expoſed in the ſame manner, a glaſs-egg, whoſe ball, and a little part of its ſtem, was filled with ſome of the ſame oil of turpentine, which, thus ſoon ſubſided about half an inch; whence it deſerves to be conſider'd, why, if cold be cauſed by admiſſion of actual particles, they ſhou'd contract the oil without being able to freeze it, and freeze the water without contracting, but expanding the ſame.

10. After

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10. After the manner lately deſcribed, we ſuſpended a ſmall glaſs bubble fill'd with water, and hermetically ſealed, in a glaſs of ſpirit of wine, and expoſed them to the air of a cold night, whereby the water was congealed, tho' the ſpirit continued its natural fluidity. But another bubble of water ſuſpended in common brine, at the ſame time with the former, was no more frozen than the brine itſelf, that is, not at all. The ſame ſucceſs, alſo, attended the repetition of this experiment twice; however, upon a fourth trial, we found the bubble burſt, within two hours after it had been expoſed in a mixture of ice and ſalt, with ice adhering to the upper part of the bubble, whilſt the other was crack'd, in lines that run from a point. And more ice, we ſuppoſed, wou'd have appear'd, had it not been diſſolved by the ſalt water, getting in at theſe cracks.

11. We fill'd a ſmall glaſs-bubble with fair water, ſealed it hermetically, and ſuſpended it in the middle of a large empty wide-mouth'd glaſs well ſtop'd; then expoſing it to a ſufficient degree of cold, we found that the water froze, and crack'd the bubble, without the intervention of any viſible liquor.

XVIII.

Experiments and obſervations upon ice.

1. We are inform'd, that to the inhabitants of ſome parts of the *Eaſt-Indies*, it has appear'd a thing incredible, that the fluid body of water ſhou'd, in a few hours time, be naturally converted into a ſolid. This, thro' its commonneſs, appears little aſtoniſhing to us; however the degrees of coheſion in the parts of ice, have not been ſettled; nor perhaps can we arrive any higher than a bare conjecture in this particular: for different degrees of cold, may poſſibly give different degrees of compactneſs thereto; and accordingly, I have been aſſured, that the ice in *Ruſſia*, is much harder than in *England*.

2. I have had thoughts of ſeveral methods to eſtimate the coheſion of the parts of ice; and purſued the matter far enough to ſatisfy myſelf, that its ability to ſupport a weight is ſurprizingly great, conſidering that common knives will eaſily cut it.

3. We placed a piece of ice, three inches long, three broad, and leſs than $\frac{1}{4}$ inch thick, croſs-wiſe on a frame; ſo that the two parts whereon the ice reſted, were diſtant near three inches from each other; then fixing a ſcale to an iron hook, we hung it in the middle of the ice, and lay'd weights thereon, till the hook, whoſe part that reſted on the ice was $\frac{1}{4}$ inch, forced itſelf downwards, and, at length, the ice broke, the hook having firſt deſcended half thro' the ice at one end, and a third part thro' it at the other, of the inciſion. The weight applied was ſeventeen pounds averdupoize, and one hundred ſeventeen ounces troy.

4. This experiment we repeated with a piece of ice 2 $\frac{1}{2}$ inches broad, and $\frac{1}{4}$ inch thick, placed in the frame at the diſtance above-men-

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PHYSICS. tion'd; but the weight required to break it, was ſeventeen pounds averdupoize, and forty-eight ounces troy. The horizontal part of the hook had, however, cut more than $\frac{2}{3}$ thro' the ice at one end, and nearly half thro' at the other.

5. We have found, that by ſtrewing bay-ſalt upon thin plates of ice, placed on a flat board, the ice wou'd, in ſome meaſure, be diſſolved, and afterwards ſo ſtrongly frozen to the board, that we were obliged to beat it off piece-meal, with an iron inſtrument, if we wou'd disjoin them; nay, the parts of ice adhered ſo firmly in the pores of wood, that ſome of them, notwithſtanding this force, ſtill continued unmoved.

6. Having thrown a conſiderable quantity of ſalt upon ſome ſolid pieces of ice, there was ſuddenly produced a ſmall crackling noiſe; and for a conſiderable time after, there manifeſtly aſcended a large white ſteam, or thick ſmoke therefrom.

7. Upon pouring *Aqua fortis* on cakes of ice, wherein was abundance of bubbles, it preſently penetrated thro' them with a conſiderable noiſe, that ſeem'd to be the cracking of the ice, whilſt the liquor underneath it, might be taſted manifeſtly ſour. Oil of vitriol, alſo, afforded the ſame phenomena, but in a much greater degree, yet without ſeeming to crack the ice it paſſed thro'; ſo that if only a few drops hereof were let fall, it immediately ſhew'd itſelf exceeding corroſive on the oppoſite ſide of the ice: and this we found it wou'd do thro' three plates of ice, laid one upon another, each whereof was about $\frac{1}{3}$ inch in thickneſs.

8. Decoctions of ſage, roſemary and parſley, being ſeverally expoſed, in ſmall earthen pipkins, to freeze, they were totally converted into ice, wherein appear'd no reſemblance of the reſpective plants; only that afforded by the decoction of ſage, had a very uneven ſurface, and far more rugged than the other two, which were neither of them ſmooth; and all of them, but particularly the decoction of ſage, yielded a ſofter ice than the common.

9. Some freſh lemmon juice, froze in a wide-mouthed glaſs, afforded an ice very odly figured, eſpecially in one part, where it finely repreſented naked trees.

10. Snow-water ſet to freeze in ice and ſalt, afforded pretty figures in its congelation, with bubbles produced therein, ſo minute, that the whole maſs of ice remain'd very tranſparent.

11. Upon mixing a large quantity of ice in groſs powder, with ſome whole bay ſalt, and ſtirring them together, a viſible fume overſpread the containing veſſel, like a fog; and when riſen above its brim, fell down again in ſtreams: theſe fumes alſo play'd in great plenty upon the ſurface of the mixture, as a miſt upon a pond, being ſome of them unable to riſe higher. The phenomenon continued for a long time, tho' I cou'd not be poſitive, that theſe fumes were cold;

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12. *Olaus Magnus* tells us, "that the ice in the cold northern cli-
"mates, about the beginning and middle of winter, has its coheſion
"of parts ſo ſtrong, that at the thickneſs of two inches, it will ſup-
"port a man; at the thickneſs of three, an armed dragoon; at that
"of fourteen, a company or band of ſoldiers; and, laſtly, that if it
"be a yard thick, an army, of ten thouſand men, may march there-
"on." This indeed, is no accurate way of meaſuring the coheſive force of ice; becauſe the diſtance of the part that ſupports the weight, from the ſhoar, is not here regarded, tho' the remoter parts of the ice reſt hereon; for the ice being conſider'd as a lever, the place of the weight upon it, muſt, by all means, be determined; ſince the ice may reſiſt a conſiderable preſſure near the banks, tho' but a very ſmall one near the middle of a frozen river. However, 'tis plain from this general obſervation, that the ice of a river, at ſuch a particular thickneſs, will in any part of it, ſuſtain the reſpective weights above-mention'd; and therefore, even at a point, the fartheſt removed from the prop of the lever; which ſhews an immenſe force of coheſion in ice.

13. I proceed to the obſervations of travellers and ſailors, made upon ice. Capt. *Weymouth* tells us, that, in his voyage to diſcover the north-weſt paſſage, he found ice almoſt as hard as a rock. He relates farther, "that finding ſome pieces broken off from an iſland "of ice, they afforded very good freſh water." An old ſea captain, who had often ſailed into the frigid zone, aſſured me, that when his ſhip had been immured with ice, ſo that no ſalt-water cou'd be come at, he made wells in thick pieces of ice to receive the liquor that thaw'd therein, which he found, tho' on the main ſea, to be good, freſh, potable water, and fit for all neceſſary uſes; ſo that he never fear'd the want of ſuch water there. There's a poſſibility, however, that this ice, which affords freſh water in the ſea, is congealed ſnow, (not the ſalt-water frozen) that lies upon the ſurface, and adds to the height of the ice underneath; 'tis alſo poſſible, that ſuch ice may have come from rivers that diſcharge themſelves into the ſea, as thoſe vaſt quantities obſerved about *Nova Zembla*, and the ſtreights of *Weigats* are allow'd to deſcend from the great rivers *Oby*, *Jeneſce*, &c. and this carries the greater poſſibility, becauſe the main ſea is ſeldom or never frozen.

14. The next thing I ſhall conſider is, the magnitude of ſingle portions of ice. The old ſea captain above-mention'd told me, he ſeveral times faſten'd his ſhip to maſſes of ice, that reach'd thirty fathom under water; and that he once lay aſide of a piece that reſted on ground in fifty fathom water. None of theſe, he ſaid, roſe with their heads very high above the ſeas ſurface; he thought not much more than

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PHYSICS. a tenth part of their whole length; and that ſnow, ſucceſſively falling thereon, depreſs'd them ſo low; which often melting within two or three days, wou'd ſubſide to a third or fourth part of its former height, and become ſolid ice. Capt. *James* tells us, he one day ſailed by an icy mountain of a height incredibly greater than what we lately obſerved from him, to be taller than his main-maſt. But the famous ſailor Mr. *Baffin* ſays, "on the ſeventeenth of *May*, we ſailed by "many great iſlands of ice, that were above two hundred feet high "above water; and one in particular, that I meaſured to be two "hundred and forty feet; whence if only ¼ of the ice be extant a-"bove the ſurface of the ſea, this piece of ice muſt have been one "hundred forty fathom long; and this proportion, I have known "to hold in ſome ice; but I don't affirm it in all." Capt. *James* obſerved ſome flat pieces of ice, to meaſure one thouſand of his paces in length.

15. Of compounded portions of ice, I find the following accounts. Mr. *Hall*, in his voyage to diſcover *Greenland*, tells us, he met with an huge bank of ice twenty four miles long. Another *Engliſh* ſailor relates, "that, even in *June*, the ſea where he lay, was cover'd with ice, as far "as he cou'd diſcern all around him, from a conſiderable eminence, "except within a quarter of a mile from the ſhoar." Whence that vaſt extent of ice ſhou'd appear as one floating iſland. The *French* hydrographer *Fournier*, relates, "that their fleet ſailing to *Canada*, in the "year 1635, met with ſeveral maſſes of ice, as high as ſteeples; and "in particular, one or two, in ſome places being flat, and in others, "riſing up in frightful hills, along which they coaſted, for above forty, "or even eighty leagues together; and here," ſays he, "are often, in "the month of *Auguſt*, ſeen floating pieces of ice much larger than "ſhips." *Olaus Magnus* aſſures us, "that battles are fought as well "upon the ice of the northern ſeas, where, during the ſummer, fleets "uſually engage, as upon ſolid champaign ground; let the contending "armies, with all their artillery, be drawn up ever ſo cloſe together." And 'tis a common thing in the more northern nations to take large journeys, with heavy carriages, over the vaſt plains of ice. 'Tis well known alſo, that the whole *Swediſh* army lately marched over the frozen ſea to the iſland of *Zealand*. Nay, even in the eaſtern regions, the ſea itſelf has been congealed to a prodigious breadth. "*Manaſſes*, in his "annals" ſays *Bartholine*, "relates it as an extraordinary thing, that in "the reign of *Theophilus*, there happen'd ſo hard a winter, that it there "froze the ſea into ice, to a vaſt thickneſs, and a ſtony hardneſs." And "according to *Glycas*, "in the year 775, the ſea was frozen along the "mediterranean coaſts, to the diſtance of fifty leagues, into ice as hard "as a rock, and to the depth of thirty cubits; at which time, al-"ſo, there fell ſo large a quantity of ſnow, that added thirty cubits to the "height of the ice."

16. We

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in a huge piece of ice, under which they ſhelter'd themſelves from ſtormy winds; they tell us, it was cover'd on the top with earth; that they found forty eggs thereon; that its colour was a perfect azure; whence ſome of their crew affirm'd it to be frozen land; for it lay ten fathom high above the water, and deſcended eighteen fathom under it, that is, quite to the bottom. This colour in ice has been alſo obſerved by Capt. *James*; ſo that perhaps *Virgil* might not ſpeak improperly, when he gave the epithet blue, to the ice of the frigid zone. 'Tis very conſiderable, if true, what *Olaus Magnus* ſays, "that when, towards the beginning of *April*, the ice begins to thaw, "'tis very unſafe to venture upon it, unleſs in a morning; for the "heat of the ſun renders it ſo brittle, that tho' it lately ſupport-"ed armed dragoons, a naked man can now ſcarce walk upon it." He adds, "that when the ice breaks, it makes a very loud and "dreadful noiſe, like that of thunder, or an earthquake; but eſpe-"cially, if it happens in the night." And to this particular, Mr. *Hall* agrees, who tells us, that "as they ſteer'd by a huge and high iſland "of ice, there fell a piece from the top thereof, with a report equal to "that of five cannons; and that about twelve of the clock one night, "they were ſuddenly compaſs'd round with great iſlands of ice, that "made a moſt ſurprizing hideous noiſe." There are many concurring teſtimonies given of this noiſe occaſion'd by ice, tho' it ſometimes ſeems to proceed from the daſhing of the pieces one againſt another; but if it happens at the time the ice appears to cleave ſpontaneouſly, it ſeems difficult to aſſign its cauſe. *Olaus Magnus*, indeed, with ſome probability, aſſigns it to the warm exhalations of the earth; and agreeably hereto, I remember, that ſome pieces of thick ice being brought out of a cool place into a warm room, made a ſmall crackling noiſe. I am informed, however, by a native of *Poland*, that great cracks and loud frightful noiſes, happen as well by the action of exceſſive cold, as a thawing heat upon the ice. And indeed, we ſometimes obſerve the ground to be cleft in very violent froſty weather. The old ſea captain, whoſe teſtimony I have twice uſed already, remarks, that large tracts of ice have a power to deaden the wind; for that having been diſtreſs'd by ſtormy weather, and driven near huge ſhoals thereof, he had unexpected found a calm, to his great ſurprize; and ſeveral times ſailing from the ice upon a ſmooth ſea, he has met a ſtorm at ſome diſtance from the ſame. He adds, that a *Dutch* ſailor, who frequented the northern ſeas, aſſured him of having ſeveral times obſerved the like wonderful property of the ice.

XIX.

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XIX.

Experiments and obſervations upon the duration of ice and ſnow, and the deſtruction thereof by air and ſeveral liquors.

1. 'Tis generally thought there are liquors potentially hot, wherein ice will ſooner diſſolve than in water. To bring this to the teſt of experiment, we attempted to freeze water in bullet-moulds, that we might gain Pieces of ice exactly of the ſame magnitude; but not being able to procure any moulds, whoſe cavities were of equal dimenſions, we ſubſtituted a glaſs tube in their ſtead; wherein having frozen ſome water into a cylinder of ice; we divided it exactly into equal portions. Theſe pieces we ſeverally put into different liquors at the ſame time, whilſt exact notice was taken, by means of a ſecond pendulum, furniſhed with an index, and a divided dial-plate, how long they were in diſſolving.

Two ſets of our experiments, were made with cylinders of ice an inch long, and about half an inch in diameter, wherein we obſerved as follows.

I. In	Oil of vitriol	the ice diſſolved in	5	minutes.
	Spirit of wine		12	
	Aqua fortis		12¼	
	Water		12	
	Oil of turpentine		44	
	Air		64	

II. In	Oil of vitriol	the ice diſſolved in	3	minutes.
	Spirit of wine		13	
	Water		26	
	Oil of turpentine		47	
	Sallet-oil		52	
	Air		152	

2. We morever thought it worth trying, what difference there wou'd be in the duration of pieces of ice of the ſame bulk and figure, ſome whereof were made from water, others from wine, milk, oil, urine, *&c.* when expoſed to thaw in the air, or other fluids; and alſo whether motion wou'd impart heat to ice, by rubbing two pieces thereof one againſt the other: and indeed, I found ſuch an attrition haſten the diſſolution in that part of a plate of ice, which ſuſtain'd it.

3. And, by the way, upon throwing ice into a certain cold liquor, it has preſently diſſolved, and produced a great degree of heat.

4. The effects of cold do not always depend upon the actual preſence of its manifeſt efficients; for when theſe have once brought a diſpoſed ſubject to a ſtate of congelation, it will, ſometimes, continue therein, tho' the operation ceaſes. And, we frequently ſee that when a certain texture is produced in a body, it remains there till ſome other agent over-powers and removes it. Tho' ice and ſnow may ſeem to melt away

of

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diſſolution appears to be the action of the air upon them, that is heated by the ſun's rays, or ſome warm exhalations from the earth; and, accordingly, we ſee that great compacted maſſes of them, will, above ground, remain long undiſſolved, when the warm air has not free admiſſion into the pores thereof; but if cloſe piled up in proper reſervatories below the ſurface of the earth, they may be preſerved for a ſtill longer time *.

The method of making reſervatories, and preſerving ſnow in *Italy*, take as follows, from Mr. *Evelin*. "The ſnow-pits in *Italy* are ſunk in the "moſt ſolitary places, and uſually at the foot of a hill, to protect them "from the ſun, fifty feet deep, in form of an inverted truncate cone, "with their mouth, twenty five in diameter. The ſides of the pit are "ſo joiced that the boards may be nailed very cloſe thereon. About a "yard from the bottom is fixed a ſtrong frame, upon which is placed "a kind of a wooden grate. The cover of the mouth is double thatched, "with reed or ſtraw, upon a copped roof, on one ſide whereof, ap-"pears a thatched narrow door-caſe; hipped on like the top of a dor-"mer, which compleats the whole. To preſerve their ſnow herein, they "lay clean ſtraw upon the grate, to prevent its running thro' whilſt they "beat it to a hard icy cake near a foot thick; upon which a layer of ſtraw "being laid, they place more ſnow thereon, and ſtraw upon this; and "thus continue layer upon layer, till the pit be filled: when they cover "the whole, thick, with ſtraw or reed, and ſhut the door. The grate "is contrived to drain off the liquor that might run from the ſnow, if "by accident any ſhould melt, which would, otherwiſe, haſten the diſ-"ſolution of the reſt; and upon this account the bottom is but ſlightly "ſteen'd. The curious preſerve a circle of tall, ſhady trees, about the "mouth of the pit."

5. The *Dutch* relate, that in their *Nova Zembla* voyage, tho' the weather proved fair and ſun-ſhiny, yet the heat was not ſtrong enough to melt the ſnow on the twenty third of *June*. Nay, in warmer climates, ſnow will remain, during the whole ſummer ſeaſon, undiſſolved upon the tops of high mountains. And Captain *James* ſays, that "in *July* "and the beginning of *Auguſt*, we expoſed ſome pieces of ice, that "meaſured two feet ſquare, to the heat of the ſun in the ſhip's boat; "whereon the rays played ſtrongly; yet, notwithſtanding that, and "the warmth of the ſhip, wherein we kept a large fire, they lay eight "or ten days before they would melt." He farther obſerves, that "the ground continued frozen till *June*, tho' the weather was then hot "upon the ſhoar." The ſame perſon alſo relates, that a but of wine, which ſtood all the winter upon deck, continued firm frozen till the month of *May*.

* 'Tis a remarkable obſervation of M. *Homberg*, that ice in ſummer diſſolves much ſooner in *Vacuo*, than in open air. *Hiſt. de l'Academ.* A. 1708, *p.* 26.

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XX.

Conſiderations and experiments upon the Primum Frigidum.

1. The diſpute about the *Primum Frigidum* is become famous among naturaliſts; ſome contending it is the earth, others the air, and ſome of the moderns, that it is nitre; but all ſeem to agree that there is ſome particular body ſuperlatively cold in its own nature, by partaking whereof, all other cold bodies obtain that quality.

2. But, in my opinion, before men had ſo deeply engaged in this diſpute, they ſhould have enquired whether there were any ſuch thing as a *Primum Frigidum*; for tho' I will not reſolutely deny its exiſtence, yet, I think it may well be queſtioned, and that upon ſeveral accounts.

And firſt, it is very diſputable, whether cold be a poſitive quality, or a bare privation of heat; and till this queſtion can be determined, it muſt ſeem improper to enquire which is the *Primum Frigidum*.

'Tis, indeed, generally taken for granted, that heat, moiſture, dryneſs, gravity, *&c.* have each of them a principal ſubject to reſide in, yet this ſeems to be only a groundleſs fancy; for there are many qualities, as gravity, figure, motion, colour, ſound, *&c.* of which no true and genuine primary ſubject is aſſignable: and ſince heat and cold are look'd upon as qualities diametrically oppoſite, it will be very hard to ſhew that there is a πρῶτον δεκτικὸν, of the former; ſince ſtones, metals, plants, animals, and almoſt all ſolid bodies, will, by motion, become hot.

Among the bodies generally alledged for this purpoſe, there is not one that ſeems to deſerve the title of *Primum Frigidum*. *Plutarch* ſuppoſes the earth to be the *Primum Frigidum*; yet we ſee the earth is frozen not by its own cold, but thro' its vicinity to the air; for the congealing cold, even in the midſt of winter, affects only its ſurface where it borders on the air, and ſeldom penetrates above a few feet into its ſubſtance; and, therefore, if the earth be any way protected from the air, it will remain unfrozen all the winter long; as may appear from that remarkable practice in the great ſalt-marſhes of the *French* Iſlands of *Xaintonge*, where, when the ſeaſon of coagulating ſalt by the heat of the ſun is paſt, the owners, by opening certain ſluices, overflow all the banks and dams that divide the ſalt-ponds; for if they left their works uncovered, the froſt would make a great havock among them.

Beſides, the earth, upon this ſuppoſition, being the coldeſt, as it is the heavieſt and moſt ſolid of the elements, it is improbable that thoſe exceſſively cold agents, that freeze the clouds into ſnow and hail, ſhould be terreſtrial exhalations. And 'tis not eaſy to ſay, why, if elementary corpuſcles, ſteaming from the earth, have ſuch a congealing power where they are diſunited, and barely interſperſed among the particles of air, the maſs of the earth it ſelf, from whence thoſe exhalations are ſuppoſed to proceed, ſhould not be able alſo to freeze water.

Another

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the earth; from whence ſome would ſhew, the earth to be, naturally, neither hot nor cold. And even where there appear no manifeſt ſigns of theſe fires, perſons, who deſcend to the bottom of deep mines, have complained that a very little exerciſe would put them into a violent ſweat: and the learned M. *de Claves*, who hath written of precious ſtones, affirms, that in ſuch mines, the ſubterraneal vapours are ſo thick and hot, that the miners are obliged to work in their ſhirts. I am not, however, ſatisfied, that thoſe deep places would have appeared as hot, when judged of by a ſealed weather-glaſs, as they did to the miners bodies; tho' the poſſeſſor of a lead mine aſſured me, he did not uſually find any difficulty of breathing therein, notwithſtanding the ſame diſpoſition to ſweat; and others, alſo, have not complained of having their reſpiration incommoded in ſuch places, unleſs by accidental damps: and the author lately mention'd, expreſly affirms, that the ſame effect is obſerved, in the bowels of the earth, as well in ſummer as in winter. Beſides, 'tis generally found, that very deep wells and ſprings freeze not; but the water often comes up ſmoaking from thence: which argues that, at leaſt, the earth wherein it lay, or thro' which it paſs'd, was free from ſuch a degree of cold, as might be expected if the earth were the *Primum Frigidum*. Nor can it be reaſonably pretended, that the ſubterraneal heat, proceeds from the rays of the ſun; ſince they heat not the earth above ſix or ſeven feet deep, even in ſouthern countries. And if the lower part of the earth were, of its own nature, cold, and receiv'd the heat it affords, only from the ſun and ſtars; the deeper men deſcend therein, the leſs degree of heat and ſteams they would meet with; which is contrary to our *French* author's obſervation.

Morinus, another *French* author, who had the curioſity to deſcend himſelf into the mines of *Hungary*, ſome of which are three or four hundred fathom deep, relates, that after he had deſcended about an hundred fathom, he came into a very warm region of the earth, which laſted to the bottom of the mine; and is ſo hot, both in winter and ſummer, that the labourers uſually work therein without their clothes: he adds, that himſelf was ſcarce able to bear the heat, tho' the external air was very hot; it being fair weather, and in the month of *July*. And he farther declares, he was told by the overſeers, that, 'twas univerſal, the lower they deſcend, beyond a hundred fathom, the hotter it grows. But having, my ſelf, been to the bottom of ſome mines, I ſuſpect, that this degree of heat, obſerv'd in the *Hungarian* mines, might in great part, proceed from the peculiar nature of the place, or of the minerals generated there; and not wholly from their vaſt depth beneath the ſurface of the earth. For, ſeveral mixtures of bodies, not actually hot, will produce a conſiderable

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PHYSICS. degree of heat. And very credible eye-witneſſes have affirmed, that, in ſome parts of *England*, they dig up large quantities of a kind of mineral, ſuppoſed to be vitriolic, which, by the bare addition of common water, will grow ſo hot as almoſt to take fire. So that the *Hungarian* mines being deep, and not deſtitute of water, it may be ſuſpected, that either this fluid, or ſome peculiar mineral ſpirit, or juice, may, with the mineral, produce a warm ſteam, which, for want of ſufficient vent, in thoſe cloſe places, yield a conſiderable heat. And this conjecture may be countenanced by three circumſtances, which I take notice of in our author's narrative. For firſt, the ſmoke that plentifully aſcended out of the mine, thro' the perpendicular groove, conſiſted of fetid exhalations, which were ſo ſaline and fretting, as frequently to corrode and ſpoil the wooden ladders, and the iron inſtruments of the diggers. Secondly, the overſeers of the mines told *Morinus*, that they, in ſome places, met with veins of hot minerals, which augmented the heat of the place. And laſtly, as our author deſcended into the gold-mine at *Cremnitz*, he found in one place, the heat to increaſe gradually, and, at length, to exceed what he had met with in any other mine; and afterwards, coming into a ſpacious room, that abounded with ſmaragdine vitriol, from whence this heat proceeded, he found, beſides a ſharp ſpirit, very offenſive to his throat, a heat that made him ready to faint away with ſweating. And, elſewhere, the ſame author remarks, that ſuch hot mines of vitriol, or ſulphur, may be found, even near the ſurface of the earth, and diffuſe a heat all around, to a very great diſtance.

But if it be objected, that this ſubterraneal heat is adventitious to the earth, which remains ſuperlatively cold of its own nature; it may be reply'd, 'tis ſomewhat ſtrange, that nature ſhould have intended the earth for the *Summum Frigidum*, and yet a great part thereof be conſtantly kept warm, either by the ſun, as under the torrid zone, or by ſubterraneal fires.

But if it be pretended, that when the earth is ſaid to be the *Primum Frigidum*, not the elementary earth, but ſome body mixed with it, is thereby meant, I deſire to know which of the many bodies that make up the terreſtrial globe, muſt be fixed upon for this purpoſe, that we may examine its claim; in the mean time, I conclude, that the earth has none ſuch; ſince, upon this ſuppoſition, a colder body, than that is allowed to be, gives it the greateſt degrees of coldneſs it can poſſeſs. I muſt, however, diſſent from the learned *Gaſſendus*, in thinking the earth to be naturally no more cold than hot. For its inſenſible parts, like thoſe of other firm bodies, being heavy, and perhaps groſs, and either having no conſtant motion, or, at leaſt, a far more gentle one than our organs of ſenſe; it ſhould follow, that the earth muſt ſeem cold to us, unleſs it be, ſome way or other, put into an unnatural degree of agitation: and, for the like reaſon its not improbable that

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that pure earth, ſhould, in its own nature, be colder either than pure water or pure air; ſince the earth being a ſolid body, its component particles are at reſt among themſelves, or, at leaſt, mov'd with an almoſt infinite ſlowneſs; whilſt water and air, being fluids, their component particles muſt be in a different, reſtleſs motion, and, conſequently hotter; that is, in a ſtate wherein the various agitations of their more minute particles is more vehement. PHYSICS.

And if thoſe who plead for the earth in this caſe, had declared they mean not the pure or elementary earth, but part of the terreſtrial globe, diſtinguiſhed from the ſea and other waters; and would alſo have earth, in this ſenſe, to be only the *Summum Frigidum*; perhaps they might have a better plea for their opinion, than thoſe who contend for the water or the air; ſince the *Dutch*, who ſailed thrice to *Nova Zembla*, and once wintered there, affirm, that the higheſt degrees of cold, are not to be met with on the main ſea, which is moſt expoſed to the operation of the air and water, but either upon land or near it.

And *Fournier* tells us, that "in the year 1595, the *Hollanders*, being "intercepted by icy ſhoals, in the ſtreights of *Weigats*, and meeting with "ſome *Muſcovites*, were told by them, that neither the northern ſea, nor "that of *Tartary*, were ever froze, but only that ſtreight, and the ſea "contiguous to the ſhores of ſome bays and gulphs," and our author affirms, in general terms, that the main ſeas never freeze.

On the contrary, I have been told, that in *Siberia*, a northern province of *Ruſſia*, the ground is thaw'd, during the ſummer, only about two feet deep, whilſt it ſtill continues frozen below; tho', by the way, there, notwithſtanding, grows good corn on the ſurface.

That water ſhould be the *Primum Frigidum*, is contrary to experience. For, not to mention how very difficult it would be to prove that abundance of cold bodies, as gold, ſilver, cryſtal, fuſible ſtones, *&c.* contain any water; nor to urge the arguments that ſome contenders for the ſuperlative coldneſs of the air employ, I ſhall content my ſelf with this obvious phenomenon of cold, that in receptacles of water, congelation begins at the ſurface, where the fluid is expoſed to the immediate contact of the air. Now, this ſufficiently argues that the air is colder than the water; ſince it is able not only ſenſibly to refrigerate, but deprive it of its fluidity; whilſt, if the water it ſelf were the *Primum Frigidum*, it either ought to be always congealed, or we may juſtly demand why the glaciation thereof, ſhould not begin in the middle, or at the bottom, as ſoon as at the top.

'Tis a received tradition, indeed, among the water-men and ſome others, that the rivers and ponds, alſo, are frozen, firſt at the bottom, and begin to thaw there. But, 'tis evident, that in water expoſed to freeze, in large veſſels, the congelation begins at the upper ſurface, and thence, as the cold prevails, the ice increaſes and thickens downwards;

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PHYSICS. wards; and for this reeaſon, frogs retire, in froſty weather, to the bottom of ditches, whence I have taken many of them, very briſk and vigorous, from under the thick ice that covered the water: and I have been inform'd, by an obſerving perſon, that, at leaſt, in ſome places, 'tis uſual, in winter, for ſhoals of fiſh to retire to thoſe depths of the ſea, and rivers, where they are not to be found in ſummer. But if rivers were frozen firſt at the bottom, we muſt, very frequently, meet, in the emerging pieces of ice, the ſhapes of thoſe irregular cavities and protuberances that are often ſeen in the uneven ſoils over which rivers take their courſe; yet thoſe pieces of ice are generally flat, as if generated on the ſurface of the water. Moreover, if even deep rivers freeze firſt at the bottom, why ſhou'd not ſprings and wells freeze firſt at the bottom too? But that which deceives our watermen, is, they frequently obſerve flakes of ice aſcend from the bottom of rivers to the top, where, it often happens, that after a hard froſt has continued a while, theſe emerging pieces of ice, contribute greatly to the freezing over of rivers; for, coming in ſome of the narrower parts of them, to be ſtopped the ſuperficial ice, that reaches on each ſide of the river, far from the banks towards the middle; thoſe flat icy bodies are eaſily cemented by the violence of the cold, and, by means of the contiguous water, to one another; and ſo, by degrees, ſtreightning, and, at length, choaking up the paſſage, they ſtop the other flakes of ice, that either emerging from the bottom, or looſened from the banks of the river, are carried down the ſtream towards them; and thoſe being alſo, by the ſame cold, cemented to the reſt, the river is, at length, quite frozen over. And the reaſon why ſo many flakes of ice come from the bottom of the river, ſeems to be, that, after the water has been frozen, all along, near the banks, either the warmth of the ſun, or ſome other accident, thawing the ground, or otherwiſe, looſening many pieces of ice, together with the earth, ſtones, *&c.* whereto they adhere, from the more ſtable parts of the banks, theſe heavy bodies carry down with them the ice wherein they lie; but then the water at the bottom of the river being warm, in compariſon of the air, in froſty weather, the ice, by degrees, is ſo diſſolved in thoſe parts, by which it held to the ſtones, earth, or other heavy bodies, that the remaining portion, being ſpecifically lighter than water, gets looſe, emerges, and, perhaps, carries up with it ſtones and clods of earth, that may yet ſtick thereto, or be incloſed therein; the ſight whereof perſuades the water-men, that ſuch flakes of ice were generated at the bottom of the river; tho' a large piece of ice may buoy up and ſupport bodies, of that kind, of a great bigneſs, provided the ice and they together, exceed not the weight of an equal bulk of water. Thus Captain *James Hall* relates, that upon a large piece of ice in the ſea, they found a ſtone which they judg'd to be three hundred pound weight.

Beſides,

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this we may add, what was lately obſerved of the perpetual fluidity of the main ſea, and of the overflowing the ſalt-works in *France*; from whence the water ſeems not diſpoſed to receive any very intenſe degree of cold at a conſiderable diſtance from the air: for we formerly obſerved, that the congealing cold penetrates nothing near ſo deep as the thickneſs of ſome pieces of ice found in the ſea, might lead one to ſuſpect; theſe being only maſſes form'd of many flakes and fragments, which running upon or ſliding under one another, are, by the congelation of the intercepted water, cemented together into a bulk miſs-ſhapen and unweildy. Thus Captain *James* informs us, that "it ſeldom rains in "*Charlton* iſland after the middle of *September*, but ſnows: and the "ſnow," ſays he, "will not melt either on the ſhore or ſands: when "it ſnows at low-water, the ſands are all covered over with it, which "the half-tide carries off into the great bay; and every low water "the ſands are left clear: thus it daily gathers, till the latter end of "*October*; and by that time, it renders the ſeas ſo cold, that as the "ſnow falls, it lies on the water in flakes, without changing its co-"lour; but as the winter comes on, it begins to freeze upon the "ſurface three inches, or more, in one night; which being carried "away by the half-tide, it meets with ſome obſtacle, and then runs "upon it ſelf, ſo that in a few hours, it will be five or ſix feet thick: "the half-tide ſtill flowing, carries it off ſo faſt, that by *December*, "it is grown to an infinite quantity of ice." And the famous Mr. *Hudſon* ſays, "there are prodigious ſhoals of ice in the ſea towards "the pole; many ſounds and rivers being in the lands of *Nova* "*Zembla* and *Newland* to ingender it; beſides the coaſt of *Pecora*, "*Ruſſia*, *Greenland*, &c."

I cannot, however, imagine, that water is indifferent as to heat and cold; for, bating the heat of the ſun, which is only adventitious where it operates, and which leaves many vaſt portions of water untouched; the inſenſible parts of that fluid are much leſs agitated than thoſe of our organs, and conſequently may, in regard thereto, be judged cold: for tho' water be allowed a various motion of its component parts, yet an agitation ſufficient for fluidity, is often much more ſlow than that of the ſpirits, blood, and other fluids of a human body. Thus, tho' urine continues fluid, after being long evacuated, yet its parts are far leſs agitated than when it came freſh out of the bladder. Nay, the whole body of the ſea is very cold at any conſiderable depth, as a profeſſed diver told me; and, particularly, he ſaid, that having occaſion once to deſcend about twelve or fourteen fathom deep near the northern coaſt, tho' his engine very well ſupplied air for reſpiration, and tho' he felt no other inconveniencies, yet the cold was ſo violent, that he could not bear it for above two or three hours. I have often

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PHYSICS. ten wiſhed, indeed, that he had then been provided with a thermometer, to ſhew whether the intenſe cold he felt were real, or chiefly regarded his body in that ſtate. But this is not the only perſon who has found the ſea exceeding cold; for *Beguinus* relates the ſame thing from the mouth of an overſeer of the coral-fiſhery, in the kingdom of *Tunis*. And *Joſephus Acoſta* tells us "it is remarkable, that in the "depth of the ocean, the water cannot be heated by the violence of "the ſun, as in rivers. Nay," ſays he, "as ſalt-petre, tho' it be of "the nature of ſalt, hath the property to cool water, ſo we ſee, "that, in ſome parts, ſalt-water hath the faculty of refreſhing; which "we obſerved in that of *Callao*, where they put their wine into the "ſea to cool it; whence it appears that the ocean may temper and "moderate exceſſive heat; and upon this account," adds he, "we feel "greater heat at land, *cæteris paribus*, than at ſea; and find countries "lying near the ſea to be cooler, than thoſe that are farther from it." Upon the whole, it appears, that both in very cold and very hot regions, the deep parts of the ſea are very cold, the ſun-beams being unable to penetrate to any great depth therein; and accordingly the diver, lately mentioned, told me, he could not diſcern the light of the ſun at any great diſtance from the ſurface of the water; but that as he gradually deſcended deeper, he found it grew darker, to ſuch a degree, as would ſcarce have been expected in ſo tranſparent a body as water. But this coldneſs of the ſea is not intenſe enough to entitle water to the appellation of the *Primum Frigidum*; ſince divers have not found it ſufficiently cold to freeze the water at the bottom, as the air often does at the top.

The next opinion we are to conſider, is that of thoſe, who ſuppoſe the air to be the *Primum Frigidum*.

Now, not to mention that the air is often reckoned among the hot elements; that its heat is very great in the torrid zone; nor that, according to the generality of philoſophers, the upper region, which is incomparably the greateſt part of it, always remains hot, and the lower region, alſo, in compariſon of the middle; I obſerve, that 'tis not eaſie to ſhew how the great cold in the lower parts of the ſea, proceeds from that of the air, whoſe operation ſeems not to reach very far beneath the ſurface of the water. For Captain *James*, who had very good opportunity to try it, allows not the froſt to penetrate above two yards perpendicularly downwards from the ſurface of the water, even in the coldeſt habitable regions. And this ſeems the more rational, by conſidering, that in caſe the coldneſs of the ſea proceeded conſtantly from the air, the cold would be greater near the ſurface, where 'tis contiguous to the air, than in the parts remote from it; and yet the contrary has been made appear already.

But if it be objected, that this proves no more than that the air is not the *Primum Frigidum*, and that it may ſtill be the *Summum Frigidum*; becauſe

air; to this vulgar experiment, I oppoſe that of mine, often, already, mention'd; wherein, by an application of ſalt and ſnow, water comes to freeze from the bottom, or any ſide, at pleaſure; and that too, much ſooner than the air would, even in a ſharp froſty night. And when exceeding cold weather had reduced a parcel of air, purpoſely included in a convenient glaſs, to as great a degree of condenſation, as it poſſibly could; I have, by an external application, condenſed it much farther; which argues that 'tis not mere air, but ſome adventitious frigorific particles, ſometimes mingled therewith, that produce, or occaſion, the moſt remarkable degrees of cold. And thus, by a due application, water will be congealed, whether air touches the ſurface thereof or not; or tho' bodies, which the air can neither penetrate nor congeal, interpoſe; as may appear by the experiments formerly mentioned of freezing water included in glaſs-bubbles, and ſuſpended in oil of turpentine, *&c.* And it is, here, worth obſerving, by thoſe who ſuppoſe air to be the *Primum Frigidum*, becauſe water begins to freeze at the top, where 'tis contiguous to the air; that it is there, alſo, where the ice begins to thaw.

Beſides the three opinions hitherto examin'd, there is a fourth, attributed to *Gaſſendus*, that deſerves to be ſeriouſly conſidered. This ſuppoſes the congelation of liquors, and the cold in air, water, *&c.* to proceed from nitrous particles, or exhalations, mixed therewith: but I cannot allow nitre to be the grand univerſal efficient of cold. 'Tis true, ſalt-petre ſeems to be one of thoſe bodies that are endued with a refrigerating power, and is plentifully diſperſed thro' ſeveral portions of the earth; but, perhaps, there may be ſeveral other cauſes of cold, and ſeveral other bodies qualified for its efficients.

And firſt, if cold be not a poſitive quality, but the abſence of heat, the removal of calorific agents will, in many caſes, ſuffice to produce cold, without the introduction of any nitrous particles into the body to be refrigerated. But becauſe 'tis diſputable, whether cold be a poſitive quality, or no, we urge this argument no farther, till that controverſy be decided.

Secondly, I ſee no reaſon why the great cold we have mention'd to be met with in the depth of the ocean, ſhou'd be the effect of nitrous atoms, which muſt certainly ſwarm in prodigious multitudes, to refrigerate every ſenſible particle of the ſea. Beſides, 'tis not known, that nitre, eſpecially, in vaſt quantities, reaches near ſo deep in the earth, as thoſe parts of the ſea which are found to be exceeding cold. And as the more ſubtile part of nitre is more diſpos'd to fly up into the air, than dive down into the ſea, ſo we find no ſigns of its groſſer and more ſenſible parts abounding in the ſea-water; ſince, upon evaporations thereof, it leaves no ſalt-petre behind it. But theſe conſiderations are not all that weigh with me.

For,

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PHYSICS. For, thirdly, I am not ſatisfied with what is alledg'd to prove, that the air, and adjacent parts of the earth and water, receive their higheſt degrees of cold from nitre. For tho' *Gaſſendus*, with others, ſays, 'tis nitre reſolv'd into exhalations that makes the gelid wind, which refrigerates whatſoever it touches, and penetrating into the water congeals it; this ſeems a precarious hypotheſis, until we know on what experiments the doctrine depends. For my part, I have ſeen no great effects from the ſteams of nitre, more than of other ſaline bodies, in the production of cold; and the ſpirit of it, which is a liquor conſiſting of its volatile parts, appears not to the touch, to be actually colder than many other liquors, but even potentially hot. For whether or no the exhalations of nitre be able to congeal water into ice, I have formerly obſerv'd, that ſpirit of nitre, or *Aqua fortis*, will diſſolve ice into water, nearly as ſoon as ſpirit of wine; a liquor generally allow'd to be potentially hot in a very high degree. *Gaſſendus*, indeed, aſſerts, that diſſolv'd nitre mix'd with water freezes it, and that even in the ſummer; but I muſt freely profeſs, that altho' ſome other learned moderns teach the ſame thing, I, who am no ſtranger to nitrous experiments, have never been able to ſee any ſuch effect: and 'tis ſomewhat ſtrange, that chymiſts, who make frequent ſolutions of nitre, and often with leſs water than is ſufficient to diſſolve it all, ſo that its proportion to the water muſt have run thro' almoſt all poſſible degrees, ſhou'd never, by chance, have obſerv'd any ſuch phenomenon.

But to come to our own experiments.

1. I took a pound of good ſalt-petre, and near three pounds of common water, (which was probably *Gaſſendus*'s proportion,) and put them into a large new pipkin, where they were kept conſtantly, and nimbly ſtirr'd, ſometimes in a whirling motion, and ſometimes in a more confus'd agitation, for almoſt an hour and a half, till we ſaw no likelyhood of effecting any thing thereby; for we cou'd not perceive any atom of true ice produc'd, or ſo much as any freezing of the vapours on the outſide of the veſſel: and, for this reaſon, we thought fit, at the ſame time, to try the experiment by another kind of agitation. Mixing then two ounces of ſalt-petre with about ſix of water in a conveniently ſiz'd vial, we ſucceſſively and vehemently ſhook it to and fro, till we were almoſt tired; but neither by this way was there produced any ice within the glaſs, or the leaſt congelation of the vapours on the out-ſide of it.

'Tis true, when ſo great a proportion of ſalt-petre began to diſſolve in the pipkin, the water had a ſenſible increaſe of coldneſs, which afterwards ſeem'd to diminiſh, when once the nitre was diſſolv'd; but we obſerv'd the water to be refrigerated, when, upon the diſſolution of common-ſalt, multitudes of actually cold and ſolid corpuſcles, came to be every way diſpers'd thro' it, and the coldneſs produc'd

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me, I took a good ſeal'd weather-glaſs, about ten or twelve inches long, and immerſing it into the cold mixture of nitre and water, I obſerv'd the tinged ſpirit of wine, in the ſtem, to deſcend conſiderably; and when the cold had wrought its effect, I remov'd the thermoſcope into a vial fill'd with common water, about which was plac'd a mixture of beaten ice and ſalt; wherein the ball of the inſtrument being ſet, the ſpirit of wine haſtily deſcended, two or three inches below where it ſtood when remov'd out of the nitrous ſolution. And for farther ſatisfaction, removing the thermoſcope once again into that ſolution, the ſpirit of wine in the ſtem was haſtily impell'd up, as if the bubble had been put into warm water. And once more, the glaſs being remov'd into the refrigerated water, the tinged liquor began to fall down haſtily again, and ſoon ſunk almoſt into the bubble; ſo that to avoid injuring the inſtrument, we took it out.

2. We found ſalt-petre wou'd readily diſſolve ice, and, mixed therewith, freeze the vapours of the air to the outſide of the ſingle vial, wherein we made the experiment; which ice alone would not have done: and having plac'd ſome of the ſame nitre, groſsly beaten in little heaps upon plates of ice, we manifeſtly found them to ſink therein; which ſhews they diſſolv'd it: and laying ſome upon a thick ſmooth piece of ice, we found it penetrate quite thro', whilſt the ſurrounding part of the ice remain'd of a conſiderable thickneſs.

3. We put into a large ſingle vial, almoſt full of water, as much rock-nitre, as, by the fire's ſide, wou'd diſſolve therein, then expos'd them to the air of an extreamly ſharp night, and part of the following day; whereby the ſolution was frozen ſo hard, that having broken the glaſs, we could hardly break the included maſs. But at the bottom, there appear'd ſome liquor, with cryſtals of nitre well figured, that ſeem'd to have ſhot in it; which ſhew'd the water to have been ſufficiently impregnated with the ſalt.

4. As to the ſpirituous parts of nitre, ſo far as we can judge of their temper by diſtillation, and by thermometers, they are not actually more cold than ſome other liquors, and appear rather potentially hot than cold; at leaſt, they ſeem indiſpos'd to turn water into ice: for the ſpirit of nitre will readily, as we ſaid before, convert ice into water.

From hence we may conclude, that there are bodies colder than ſalt-petre, as being able to freeze water, which that cannot congeal; and that nitre, which is ſaid to be the efficient of ice, thaws and diſſolves it; and conſequently, in regard thereto, is rather hot than cold.

5. But to ſhew, that nitre does not always, render water ſo cold as the common air, we ſuſpended a ſealed thermometer, for a conſider-

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PHYSICS. able time, in a very ſtrong ſolution thereof; when coming afterwards to raiſe it, by the ſtring whereto it hung, to avoid touching it with my hand, we found, tho' the day proved windy, the tinged liquor gradually deſcended ¼ inch; then placing it again in the ſame ſolution, the liquor again mounted to the ſame, or ſometimes a greater height; for the experiment was often repeated.

6. If my opinion be then demanded, as to the refrigerating power of nitre; I anſwer, that I have not yet ſatisfied myſelf concerning it. I acknowledge, however, that among many other bodies which exhale from the terreſtrial globe, nitrous corpuſcles may be, generally, well qualified to cool the air; and, perhaps, there may be little ſaline bodies of kin to nitre, that, at certain times, plentifully float about in ſome parts of the atmoſphere; but that this aerial ſalt, by ſome call'd volatile nitre, is true and perfect ſalt-petre, I cannot ſay: and that this ſalt alone ſhou'd be the *ſummum frigidum*, is more than I am convinc'd of; ſince there may be in the bowels of the earth many other bodies, whoſe effluvia have a power to refrigerate the air, equal to that of ſalt-petre. And as common ſalt, in artificial glaciations, is found to co-operate, as powerfully as ſalt-petre itſelf; and ſince it is undeniably diffus'd in vaſt quantities thro' the terreſtrial globe; I ſee no reaſon why that kind of ſalt may not be rank'd among the univerſal efficients of cold. And hence, too, it ſeems probable, that it may often not be the emanations of one particular body, but a peculiar conjunction of two or more ſorts, that produces an intenſe degree of cold. Thus we ſee that ice and ſnow have their coldneſs advanc'd, by the mixture of ſea-ſalt, nitre, *&c.* Nay, I venture to aſſert, that actual cold may be manifeſtly promoted, and perhaps generated, by the addition of a body not actually cold. And I doubt, whether any ſaline or terreſtrial exhalations, either ſingle, or conjoin'd, be the adequate cauſe of cold: becauſe there may be other ways of producing it, beſides by the introduction of frigid corpuſcles.

XXI.

Experiments and obſervations upon the coldneſs and temperature of the air.

We have ſeen that the air is not the *primum frigidum*, yet, I cannot allow it to be neither cold nor hot, only as it is acted upon by external agents; for if we take cold, in the obvious acceptation of the word, for a quality relative to the ſenſes of a man, whoſe organs are in a moderate temper as to cold, and heat; I am inclinable to think, that coldneſs may be attributed to the air, rather than heat, or a perfect neutrality both as to that and cold. To make a body cold, as to ſenſe, it ſeems ſufficient, that its minute particles ſhou'd leſs agitate the ſmall parts of our organs of feeling, than they are uſually agitated by the fluids of the body; and conſequently, ſuppoſing the air deſtitute of calorific and frigorific atoms, it wou'd conſtitute a fluid, which,

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which, either by the minuteneſs of its parts, or their want of vehement motion, may leſs affect the ſenſe of feeling, than thoſe fluids, and therefore appear actually cold. It is, by no means, neceſſary, that all fluids ſhou'd be as much agitated, as the vital humours of a human body; for in fiſh, and other animals, the blood and juices are always actually cold to our touch. And what reaſon is there, why the air ſhou'd not, in its natural ſtate, be a cold fluid? For as to the grand argument, that air is eaſily heated by the action of the ſun, or the fire, and as eaſily refrigerated by ice, ſnow, *&c.* and that heat and cold reign in it alternately every ſummer and winter; this only proves, that the air is ſuſceptible of both theſe qualities; but does not ſhew, that one is more natural to it, than the other. Thus water may be eaſily depriv'd of its fluidity, by the application of ſnow and ſalt, and reduced to a fluid again by the ſun or fire; and yet fluidity, not firmneſs, is allow'd to be the natural ſtate of water. But, farther, it is manifeſt, that the heat of the air is adventitious, and communicated by the rays of the ſun, or ſome other agent, naturally productive of heat in other bodies, as well as in that. 'Tis alſo evident, that upon the bare abſence of the ſun, or removal of other cauſes of heat, the air will, as it were of its own accord, become cold; whilſt 'tis but an hypotheſis, that ſwarms of frigorific atoms, diffus'd thro' the air, produce coldneſs therein, and not countenanc'd either by reaſon or experience. In ſome caſes frigorific corpuſcles may be allow'd of, yet, I ſee not why we ſhou'd have recourſe to them, when a bare ceſſation of former motion, proceeding from manifeſt cauſes, may ſerve the turn; as it will for a ſenſible coldneſs in the air. And, upon this ſuppoſition, the air ſeems as juſtly to be term'd cold, as iron, marble, mercury, cryſtal, ſalt-petre, *&c.* which men unanimouſly agree to call ſo; to all which, the argument produc'd againſt the coldneſs of the air is applicable, except that the air, being a fluid, ſooner receives and loſes the impreſſions of heat and cold than they. PHYSICS.

1. We fill'd a thermometer, to a convenient height, with well rectified ſpirit of wine, ſeal'd it hermetically, and inclos'd it in a glaſs receiver of a cylindrical form, about two inches in diameter, and a foot and a half high; and having cemented on the receiver, we left it for ſome hours that it might perfectly cool. Then, drawing out the air and watching it narrowly, we obſerv'd, that the liquor in the thermometer deſcended a very little upon the firſt extraction of any air, and ſomewhat leſs upon the ſecond; but afterwards it did not ſenſibly ſink: this ſubſidence of the liquor amounted, in the whole, to about the length of a barley corn; which we attributed to ſtretching of the glaſs, by the ſpring of the included air, when the external was withdrawn; and accordingly, upon re-admitting the excluded air, the ſpirit in the thermometer re-aſcended: and we afterwards drew out and let in the air, as before, with the like ſucceſs.

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PHYSICS. 2. We applied a very hot handkerchief to the outſide of the receiver, to try whether the included thermometer wou'd receive any impreſſion from it, when the air that had interpos'd was remov'd; but the liquor did not ſenſibly ſwell, either by this means, or by throwing thereon the concentrated rays of a candle, thro' a double convex glaſs. But the air being re-admitted into the receiver, the ſame handkerchief, heated afreſh, and applied, made the ſpirit of wine ſenſibly aſcend. Bnt till the experiment be repeated in air of differing tempers, no concluſion can hence be drawn as to its temperature,

3. Placing a ſmall ſeal'd thermometer in a glaſs, broader at the top than the bottom, that was beſmear'd on the inſide with tallow, and furniſh'd with water ſufficient to cover the ball of the thermometer, we froze that water, and took notice where the tinged ſpirit of wine reſted in the ſtem; after which, the ice being taken off from the ball in the open air of an exceeding froſty morning, the liquor immediately roſe in the ſhank a little; as it happens, when a glaſs bubble, fill'd with warm water, is ſuddenly remov'd into cold; but preſently after, the tinged liquor ſubſided a pretty way below its former mark: which ſhews, that the free air may communicate a more intenſe degree of cold, than ice itſelf.

4. The weather having continued very cold for ſome time, we plac'd an exact ſeal'd thermometer, that was made by the ſtandard weather-glaſs at *Greſham College*, in a cellar, where we had obſerved beer not to freeze during a very ſharp winter; and having looked upon it after two very froſty nights, the wind being at eaſt, we found the tinged ſpirit of wine ſtood at two diviſions, and about $\frac{1}{8}$ above the freezing mark; and on the following morning, which was very froſty, at the ſame height. Wherefore, having remov'd it into the free air, in the garden, it fell to the freezing mark; and conſequently, ſubſided above two inches beneath its ſtation in the cellar. I hence obſerve, that the air in the cellar, notwithſtanding the cold weather, was but very little warmer than that of my bed-chamber, in froſty weather; for the ſame thermometer being uſually kept there, the ſpirit commonly ſtands at that time, about two inches above the freezing mark, in the morning before my fire is made; and in the ſummer-time, when the weather is very hot, it aſcends to the eighth, ninth, and ſometimes almoſt to the tenth mark.

5. On a night, that prov'd extraordinary cold, with froſt, ſnow, and wind, the ſtandard weather-glaſs was remov'd into the garden, and left there till morning, where the ſpirit appear'd to be ſubſided above two diviſions below the freezing mark: ſo much greater was the cold of the air, than is abſolutely neceſſary to congeal water; and yet the coldneſs of this very night, did not, by antiperiſtaſis, ſo increaſe the heat of the cellar; but that a vial, containing about two or three ounces of chymical oil of aniſeeds, which was left there till nine

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moderate ſeaſons; ſince that oil is by the warmth of the air, both in the ſpring and autumn, preſerv'd liquid; as this particular parcel of oil, in the ſame vial, was kept, by the moderate warmth of my chamber, ſeveral times this winter.

6. *December* 29. 1665. A little before ten of the clock in the morning, the weather having been froſty for near a fortnight, I took a ſeal'd thermometer out of my chamber-window, and having held it a while in the open air, in the court, and alſo wetted it with water, to reduce it the ſooner to the coldneſs of the external air, I caus'd the ball of it to be held a pretty while in the reeking ſtream that came from the pump, and obſerv'd, that it made the tinged liquor conſiderably riſe; the more ſo, the longer it was kept there, till it aſcended to a great height; then carrying it up to my chamber, where there was a good fire, the ſpirit of wine began to ſubſide again; thereby, ſhewing, that the air of my chamber was colder than the reeking water of the pump.

7. On *February* 17. After it had continued froſty for three or four days, about nine or ten of the clock in the morning, I caus'd the water of a conſiderably deep well to be pump'd, for a good while, upon the thermometer, after it had been kept for ſome time in the air; which water raiſed it, by degrees, about four or five eighths of an inch higher than the former. Then I carried the glaſs to a ſpring that uſed to ſmoak in froſty weather, and having laid down the glaſs ſo as the ball might be cover'd with the water, juſt at the ſpring head, and let it reſt there a good while, I found the ſpirit but very little rais'd; ſo that in all, it ſcarce mounted five eighths above the height it had been brought to in the preceding trial. Afterwards, in the ſame place, I brought the thermometer about noon to the northſide of the houſe, where the pump ſtood, and letting it reſt againſt the wall in the open air for half an hour or more; I found, that tho' it had been that morning a ſmall froſt; and tho' the ſun did not ſhine out, yet the air was about the ſame degree of warmth, the water ſeem'd to have at the ſpring-head in froſty weather, when there was ſnow upon the ground; and conſequently the air was then much hotter than the water had been in the pump, where yet, in very cold weather, it uſually ſmoaks.

8. *February* 19. Being the third day of the continuance of a moderate froſt, I held the ſeal'd thermometer under the pump, and having caus'd the water to run for a good while upon the ball of it, I found the tinged ſpirit riſe as high as it had done many weeks before in the depth of winter, by the warmth of the water of the ſame pump.

9. On the next day, being the fourth day of the froſt, the neighbouring ſpring, which had not ſmoak'd during the precedent days, reek'd

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PHYSICS. reek'd this morning: and about noon, the weather being fair, and ſun ſhining, the ball of the weather-glaſs was kept, for a competent time, cover'd with water, juſt at the head of the ſpring; when it appear'd to have riſen higher now, by a quarter of an inch, than I cou'd make it do at the ſame ſpring-head ſeveral weeks before: but on this day, the water was a pretty deal warmer than the air; as appear'd by the ſubſiding of the ſpirit, when brought from the ſpring to my chamber; the ground being then cover'd with ſnow.

10. An ingenious man told me, he had often obſerv'd, in an exactly ſeal'd weather-glaſs, that the tinged ſpirit was higher at ſometimes, when the weather prov'd froſty, than at others, when it did not; and that having kept his glaſs with the ball in water, which was afterwards frozen, and remain'd in the form of ice for ſeveral days, he warily broke the ice from about the ball, and removing it thence into the free air of the ſame room, he found the liquor to deſcend for above three inches. The ball of this glaſs I found to be of the magnitude of a middle ſized crab, and the ſtem about two feet and a half long.

11. I formerly obſerv'd, that air included in tight ſtrong veſſels, is not ſenſibly condenſed by cold; but that when the air is, in ſome part or other, expos'd to the preſſure of the atmoſphere, it wou'd, by a degree of cold, able to freeze water, be manifeſtly contracted; tho' how great this contraction may be, has not been hitherto determined: we have, indeed, attempted to do it in the following manner; from whence it will appear, that in our climate, the cold does not condenſe the air ſo much as is uſually imagined.

And firſt, it may be proper to intimate, that among other ways we tried to meaſure the ſhrinking of the air, by ſealing it up in glaſſes, furniſh'd with long and very ſlender ſtems, that by breaking off the tips of them under water, after the included air was highly refrigerated, the water, by the preſſure of the atmoſphere upon it, might be impell'd into the cavity of the glaſs, and by its aſcent therein, ſhew how much the internal air had been contracted by the cold; but this way we found too troubleſome and difficult to practiſe with any thing of certainty; and never by this means, brought the air to loſe above a 30th part of its natural dimenſions.

12. Finding alſo ſome inconveniencies in uſing a bolt-head for this purpoſe, and any liquors capable of congelation, we at length employ'd a ſtrong brine made with common ſalt, and once obſerv'd that the cold of a froſty night, made the air ſhrink in the pipe of a glaſs-egg near five inches; and again we found that the air poſſeſſing 2057 diviſions, contracted by the cold of a ſharp and froſty night, to 1965 of the ſame: which with the utmoſt care, was the moſt we cou'd ever make the air loſe of its natural dimenſions, by any additional cold of the atmoſphere; that is, a twenty-ſecond part, and a little more than a third.

13. We

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13. We made the experiment, alſo, by the application of ice and ſalt, to the oval part of the veſſel: which rais'd the liquor higher than in the former method, near four inches. And to determine the point more accurately, we found the air contracted by this means, from 1965, to which the cold of the external air had reduced it, into 1860 diviſions; ſo that the effect of the ice and ſalt, added to that of the cold external air, did not contract the included air a tenth of its former ſpace. And here 'tis remarkable, that there was no great difference betwixt the proportion, in which the cold condens'd air, and expanded water. PHYSICS.

14. To proceed; cold may prodigiouſly hinder the warm effect of the ſun upon the air, not only in the hotteſt part, but at ſeveral times of the day, even in the heat of ſummer.

An intelligent gentlemen, who had ſeveral times ſail'd in the frigid zone, aſſur'd me, that on the coaſt of *Greenland*, he had obſerv'd it to ſnow all midſummer night. An old ſea-captain told me, that they are on the ſeas frequently peſter'd with thick fogs extremely cold, which laſt, ſome of them, for ten or twelve hours, ſome for a whole day, and others two or three days together. He ſaid farther, that lying at anchor in *Bell-ſound*, on the coaſt of *Greenland*, near a mountainous rock, he with ſome others aſcended to the top of it, which he judg'd half a mile perpendicular from the plain: here they found the weather clear, and the ſky very ſerene; and it being then *June*, the ſun ſhone vehemently hot upon them, whilſt they ſaw a thick fog, like clouds, at the bottom of the hill; but when they came down, they found the fog as they left it, very dark and exceeding cold. And Mr. *Logan*, an *Engliſh* merchant, who winter'd at *Pecora*, a northern town of *Muſcovy*, relates, that about the cloſe of *Auguſt*, they had a ſtrong froſt, which laſted for four days. Capt. *Weymouth* ſays, that in *July*, tho' he was then far from the latitude of *Nova Zembla*, yet ſailing in a thick fog, "they found their tackling ſo hard frozen, "that it ſurpriz'd them; for it was then the middle of their ſum-"mer." In the fifth voyage the *Engliſh* made to *Cherry* iſland, which lies betwixt ſeventy-four and ſeventy-five degrees of latitude, they obſerv'd, that the wind being at north-eaſt, upon the twenty-fourth of *July*, "it froze ſo hard, that the ice hung on their clothes;" and in their ſeventh voyage to the ſame iſland, they ſay, that "on the four-"teenth of *July*, the wind being northerly, they had both ſnow "and froſt."

15. To give two or three inſtances of the ſudden operations of the cold harboured in the air.

Dr. *Fletcher*, who went ambaſſador to *Ruſſia*, tells us, that "when he "there came out of a warm room into a cold, he ſenſibly drew his "breath ſtiff, and even ſtifling with the cold: ſo powerfully and ſud-"denly does the intenſely refrigerated air work upon the organs of "reſpiration.

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PHYSICS. "respiration." The chief physician of the *Russian* Emperor assured me, he has seen water, thrown up into the air, immediately fall down actually congealed into ice: and this relation Dr. *Fletcher* confirms, by declaring himself an eye-witness of the same thing. The same person farther declared, that being at the siege of *Smolensko* in *Russia*, he observed it to be so extremely cold in the fields, that his spittle would freeze in falling from his mouth to the ground; so that if he spit against a tree, for example, it would not stick there, but immediately fall to the foot of it.

16. Among the phenomena of cold relating to the air, I endeavoured to observe whether, upon the change of the weather, from warm or mild, to cold and frosty, there would appear any difference of the weight of the atmosphere, from its being plentifully furnished vith a new stock of frigorific corpuscles, whereto several of the modern philosophers ascribe its coldness. But tho' I, several times, compared an exact barometer, with a good sealed thermometer, furnished with pure spirit of wine, I could not find, that upon the coming on of clear and frosty weather, the atmosphere would very soon appear sensibly heavier than before: but I refer the matter to more frequent and continued observations than I yet have been able to make.

17. Another effect that the cold frequently has, especially in the northern countries, upon the atmosphere, is to render it more or less clear than usual; for in northern voyages the seamen frequently complain of thick and lasting fogs: on the contrary, it very often happens, that when the cold is very intense, the air grows much clearer than at other times; probably, because the cold, by condensing, precipitates the vapour that thickens the air; and by freezing the surface of the earth, keeps in the effluvia that would otherwise arise therein: it may also somewhat repress the vapours that would be afforded by the water it self; since some of our navigators observe, that when it is not cold enough to freeze the surface of the sea, it infrigidates it so, that the snow will be undissolv'd thereon.

18. A *Swedish* ambassador, with whom I had the honour to be particularly acquainted, used to say, when he saw a clear frosty day; that it then look'd like a *Swedish* winter, where, when once the frosty weather is settled, the sky is usually, for a long time, very serene and pleasant: and here in *England*, we commonly observe, the sharpest frosty nights to be the clearest. And Capt. *James* tells us, in his journal, that in *Charlton* island, on the 30*th* and 31*st* of *January*, there appeared, in the beginning of the night, more stars in the firmament, by two thirds, than ever he had seen before. I could see, says he, the cloud in cancer full of small stars.

19. An ingenious gentleman, lately return'd out of *Poland*, inform'd me, that about the twenty-first, twenty-second and twenty-third of *December* 1669, *Old Stile*, lying within three *Polish* miles of *Warsaw*, he every day beheld the sun accompanied with two parhelions, the one eastward, the other westward, almost in a direct line, and distant from it about eight

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eight or ten diameters of the ſun; and that they continued viſible from near ten to twelve a clock: the weather being extream cold, the air was as clear as could poſſibly be imagined, both night and day, and when the ſun-ſhone, appeared full of glittering ſpangles or particles of ice. PHYSICS.

20. To determine what effect the coldneſs of the air may have upon the refractions of the celeſtial bodies, ſeems a work of no ſmall difficulty.

What I have here to ſay of it, is taken from the accounts of travellers. The *Dutch*, in *Nova Zembla*, who take great pains to ſhew, by ſeveral circumſtances, that they were not miſtaken in their account of time, declare, they ſaw the ſun, after having loſt ſight of it for eleven weeks, fourteen days ſooner than it ought to have appeared to them; which difference is uſually aſcribed to the great refraction of the gelid northern air. And as for that extremely cold country, where Captain *James* wintered, it appears, by his journal, that he there made ſeveral celeſtial and other obſervations, to give him ſome notice of this refraction, which he found very conſiderable, tho' nothing near ſo great as that which the *Dutch* obſerved in *Nova Zembla*. "On the twenty-firſt "of *January*," ſays he, "I obſerved the latitude with great exactneſs, "and found it 52° 52′; which difference proceeds from the great re- "fraction:" for at his firſt arrival at *Charlton* iſland, he took the latitude with two quadrants, and found it exactly 52°. And elſewhere he ſays, "by comparing my obſervations of the time of the ſtars coming to "the meridian, we found the ſun to riſe twenty minutes too ſoon, and "in the evening, to remain above the horizon twenty minutes too "long; and all this by reaſon of the refraction," In another place he ſays, that "on *March* 15, the moon roſe in a very long oval along the "horizon." And to cite only one paſſage more concerning refractions; "I often," ſays he, "obſerved the difference betwixt clear weather, "and miſty, refractious weather, in this manner. From a little hill "near adjoining to our houſe, in the cleareſt weather, when the "ſun ſhone with all imaginable purity of air, we could not ſee "a little iſland which bears from us *South South-Eaſt*, about four "leagues; but if the weather were miſty, we could ſee it from the "loweſt place."

21. To proceed; I obſerve, that the degrees of coldneſs, in the air of different climates, are nothing near ſo regularly proportionable to their reſpective diſtances from the pole, as is uſually imagined.

In places equally diſtant, theſe from the north and thoſe from the ſouth pole, the latter are generally much colder than the former. What exceſſive cold reigns at *Moſcow*, and the parts adjacent, during the winter, whereby many perſons loſe their noſes, their toes, and ſome their lives, we have already obſerved; yet at *Edingburgh*, which is placed more northerly, by above a degree, and in the neighbouring places, the air is temperate, and the cold tolerable, the ſnow, it ſeems, ſeldom lies long on the ground after it is fallen. In an account of a

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PHYSICS. voyage made for northern diſcoveries, by Mr. *Pool*, in the year 1610, I find this paſſage, "I was certified that all the ponds and lakes were un- "frozen, tho' freſh water; which makes me hope for a mild ſummer "here, after ſo ſharp a beginning; and my opinion is, that a paſſage "may be ſoon obtained this way, by the pole, as any unknown way "whatever; becauſe the ſun gives a great heat in this climate, and the "ice made here near the 79°, is nothing near ſo huge as I have ſeen in "73°. To this agrees the teſtimony of the *Hollanders*, in their firſt voy- "age to *Nova Zembla*: "We have" ſay they "aſſuredly found that the "only hindrance to our voyage, was the ice about *Nova Zembla* under "73, 74, 75 and 76 degrees, and not ſo much upon the ſea between both "the lands; whence it appears, that not the nearneſs of the north pole, "but the ice that comes in and out of the *Tartarian* ſea, cauſed us here "to feel the greateſt cold. It is true, that in the country lying under "80°, which we ſuppoſe to be *Greenland* both leaves and graſs are to be "ſeen, with ſuch beaſts as feed thereon; tho', on the contrary, in *Nova* "*Zembla*, there grow neither leaves nor graſs, nor are beaſts there but "ſuch as feed on fleſh, yet *Nova Zembla* lies 4, 5, and 6°. more ſouth- "erly than that."

Joſephus Acoſta alſo tells us, that "in paſſing to the *Indies*, when he "came to the equinoctial, in the month of *March*, he felt ſo great a cold, "as obliged him to go into the ſun-ſhine to warm himſelf. There is, in- "deed," ſays he "no region in the world more pleaſant and temperate "than under the equinoctial, tho' it be not in all places of an equal tem- "perature; but the torrid zone, is, in ſome places, very temperate, as "in *Quitto*, and on the plains of *Peru*; in others very cold, as at *Potoſi*; "and in others again very hot, as in *Ethiopia*, *Braſil*, and the *Moluccoes*. "And again" ſays he "ſnow, hail, and frozen waters, are continually "upon the tops of the mountains; and the cold is ſo ſevere, that it "withers all the graſs, and both men and beaſts, which paſs that way, "are benummed with cold: this happens in the torrid zone, and moſt "commonly when the ſun is in their zenith."

An old ſea Captain, who has often ſailed to *Greenland*, aſſured me, that he met with two maſters of ſhips, the one from *Holland*, and the other from *Embden*, who declared they had ſailed to the lati- tude of 89 degrees, in queſt of a proper place for whale-fiſhing; the journal of which voyage, they produced him; and the captain meeting the ſteers-man of one of the ſhips, diſcourſed with him, and ſaw his journal too; which agreed with what the others had declared. And afterwards one of the maſters coming to *London*, he was there met accidentally by our captain, who brought him to ſome of the northern company, before whom he averred the foregoing relation, of whoſe truth the captain ſeem'd to be convinced. All the particulars that I could learn of this ſtrange voyage, were, that tho' they met with vaſt regions of ice, towards the ſhores, yet when they found themſelves near

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a paſſage, perhaps, as far as *Japan*; that from the north-eaſt, there came a great rolling ſea, which one of the maſters, who had been at the bay of *Biſcay*, compared to the *Spaniſh* ſea; and that the cold there was not violent, but ſuch as they could eaſily endure, and complained no more of, than they did in *Greenland*; that ſailing from *Greenland* towards the pole, they found the compaſs to vary a point, after they had advanced ſome degrees northward; then again the variation of it was, for a great while inconſiderable, and ſoon after increaſed to two points, and laſtly, at 89 degrees of latitude, even to four points of the compaſs towards the eaſt.

Mr. *Hudſon*, in his ſecond voyage, tells us, that "tho' at 71°, they "were much peſter'd with ice about the end of *June*, yet the weather "was calm, clear and hot." And *Aceſta* adds to this the account juſt delivered. "We ſee theſe differences not only on the land, but alſo on "the ſea; there are ſome ſeas where they feel great heat, as is reported "of *Mazambigus* and *Ormus* in the eaſt, and of the ſea of *Panama* in the "weſt; there are other ſeas in the ſame degree of latitude very cold, as "that of *Peru*, where I felt it cold when I firſt ſailed it in *March*, whilſt "the ſun was directly over our heads."

Martinius, in his account of *Pekin*, tells us, that "altho' the pole "be not there elevated above 42°. yet for four whole months from "the middle of *November*, all the rivers are ſo frozen over, that the "ice will ſafely bear coaches and the heavieſt burdens. This congelation" he ſays "is, for the moſt part, made in one day; but the "thawing of the ice requires many, and begins from the lower ſurface."

But not to multiply inſtances, we ſhall conclude with obſerving that *Charlton* iſland, tho' it ſeems, by the effects, to be a colder region than about *Moſcow*, and, perhaps, as cold as *Nova Zembla* it ſelf; yet captain *James* aſſigns its latitude the ſame with that of *Cambridge*, viz. 51°. the air whereof is well known to be temperate: and 'tis remarkable, that this place was found uninhabitable by reaſon of the cold; yet, in Mr. *Hudſon*'s voyage, 'tis ſaid, that "although they ran along near "the ſhore, they found no great cold;" which made them think the place to be temperate, tho' they reckoned themſelves to have then reached the 78*th* degree of latitude: and our later navigators inform us, that ſeveral parts of *Greenland* are well inhabited. An *Engliſh* ſailor alſo aſſures us, that the true height of *Puſtozera* in *Ruſſia* is no leſs than 68 degrees and a half, and yet declares it to be a town of great trade. But in *Hudſon*'s voyage, I find what is ſtill more ſtrange, *viz.* that in the eighty firſt degree of latitude, beyond which they diſcovered land very far off, "they found it, during the whole day, clear "weather, with little wind, and reaſonably warm; and beyond eighty

PHYSICS. degrees, they not only found a ſtream or two of freſh water, but "perceived it hot on the ſhore, and drank water to quench their "thirſt."

'Tis alſo remarkable, that in *New-England*, where the winter is vaſtly colder than with us, lies 10 or 11° farther from the pole than we do.

22. The next obſervable I have to propoſe about the coldneſs of the air, is, that the degrees both of heat and cold therein, may be much greater in the ſame climate, and in the ſame place, at ſeveral ſeaſons of the year, or even at different times of the ſame day, than is uſually allowed.

For the proof hereof, we ſhall produce the teſtimonies of travellers. Dr. *Fletcher*, in his treatiſe of *Ruſſia*, has this remarkable paſſage. "The country," ſays he, "differs very much from it ſelf, ſo "that 'tis ſurprizing to ſee the great alteration cauſed therein by the win"ter and ſummer. All *Ruſſia*, in the winter, lies under ſnow, which "falls continually, and is ſometimes a yard or two deep; but more to"wards the north; the rivers and other waters are all frozen up, to the "depth of a yard or more, how ſwift or broad ſoever they be; and this "continues for five months, or from about the firſt of *November*, towards "the end of *March*, when the ſnow begins to melt; and yet, in the ſum"mer ſeaſon, ſuch a new face of the whole country appears, the woods "are ſo freſh and ſweet, the paſture and meadows ſo green and flouriſhing, "there is ſuch a variety of flowers and melody of birds, that a man "cannot well travel in a more pleaſant country. But as the winter ex"ceeds in cold, ſo the ſummer inclines to too great heat, eſpecially in "the months of *June*, *July*, and *Auguſt*; which are much warmer "months with them, than with us in *England*." The like particulars have been alſo lately affirmed by the learned *Olearius*. And an acquaintance of mine, who, after having liv'd in *Italy*, paſs'd a ſummer in *Ruſſia*, aſſured me, that he ſcarce ever eat better melons than at *Moſcow*, which were there, he ſaid, of a ſtrange bulk; and this gives credit to the relation of *Olearius*, who declares, he there met with melons which weighed forty pound. At *Pekin*, the capital city of *China*, which ſcarce exceeds the forty ſecond degree of latitude, one wou'd expect, that, as the ſummer is very warm, ſo the winter ſhould be very mild; as it is obſerved of *Spain*, *Italy*, *Greece*, &c. that have the ſame or a more northern latitude; yet the learned *Martinius*, who lived many years in *China*, aſſures us, that uſually for four months together, all the rivers are ſo hard frozen, that not only all ſhips are kept immoveable by the ice, but alſo horſes, and the heavieſt carriages, ſecurely paſs upon it; and, what is very ſurprizing, he adds, that it is uſually made in one day, tho' many are required to diſſolve it. *Proſper Alpinus* tells us, that at *Grand Cairo*, where he practiſed phyſic, tho' diſtant ſix degrees from the tropic of cancer, the air, which in ſummer is almoſt inſupportably hot, is ſometimes, in winter, very

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that they could ſcarce handle the frozen ſails; and another day ſo hot, that it melted the pitch off the ſhips; and that at midnight, tobacco has been lighted by the ſun's rays, with a glaſs. And laſtly, Captain *James* gives us this account of the weather in *Charlton* iſland. "The ſixteenth "of *June*," ſays he "was wondrous hot, with ſome thunder and "lightning, ſo that our men went into the ponds, on ſhore, to cool "themſelves; tho' the water ſtill remain'd very cold. There lately "appeared ſeveral ſorts of flies; as butter-flies, butchers-flies, horſe-"flies, and ſuch an infinite number of blood-thirſty muſkitoes, that we "were more tormented with them, than ever we had been with the "cold weather. Theſe, I believe, lye dead in old rotten wood, dur-"ing the winter, and revive again in ſummer: here are, likewiſe, in-"finite numbers of ants and frogs, in the ponds upon the land."

Thus we ſee what a difference there may be in the ſame place, betwixt the temperature of the air, in the winter and ſummer. We ſhall now add, what ſeems more ſtrange, that there may be very great variations in the heat and coldneſs of the air, not only in the ſame place, but within the compaſs of the ſame day. *Proſper Alpinus* affords us an example hereof in *Egypt* it ſelf, where one would expect a much more uniform degree of heat. "In the winter," ſays he, "the nocturnal air "is exceſſive cold, but preſently grows warmer upon the riſing of the "ſun, and by noon becomes hot; but towards night, it again changes "for cold, from which irregularity proceed many diſeaſes."

The learned *Olearius*, relating his paſſage over a branch of mount *Taurus*, takes notice, that, after the middle of *June*, the air of that hot region of *Perſia*, obliged them to travel wholly by night; and yet the cold was then ſo great, that they were all benumm'd with it, and hardly able to alight from their horſes; he adds, that the ſudden change from an extream cold to the exceſſive heat they were again expoſed to on the following day, caſt, at once, fifteen of their company into a violent burning fever.

The ſame curious traveller mentions, that in another part of *Perſia*, called *Faclu*, notwithſtanding the heat of the region, towards the end of *March*, at which time they paſs'd it; they, in one night, obſerved lightning and thunder, wind and rain, ſnow and ice.

And a learned phyſician, lately arrived from the *Indies*, aſſured me, that notwithſtanding the violent heat in the day time there, he uſually obſerved the nights to be ſo very cold, that he was perſuaded ſome poſitively frigorific ſteams did then aſcend out of the earth; which makes it expedient, ſays he, for the *Engliſh*, who live in the warmer parts of *America*, to imitate the natives in keeping fires under their hammocs.

The Czar's phyſician tells me by letter, "that the winter he ſpent at "*Vologda*, which lies a few degrees to the north-eaſt from *Moſcow*, proved "much

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Physics. "much less severe than usual; for, as it happened, they had not three "days of what they, there, call winter-weather." He adds, that "the "cold, which is thought to be excessive there, hath been rare of late "years; for some *English*, who have liv'd upon the spot thirty years, "declare, that, during their time, winters are become so mild, that "the extreme cold, which used to freeze people on the road in several "postures, hath not been felt as formerly."

We will conclude with a remarkable instance taken from the journal of the *English*, who wintered at *Charlton* island. "The season in this "climate" says Captain *James* "is most unnatural; for, in the day time, "it will be insufferably hot in the sun, this being a sandy country; yet, "in the night, it will freeze again, an inch thick in the ponds: and "all this towards the latter end of *June*."

23. A third observable as to the coldness of the air, is, that in many places, its temperature seems not to depend so much upon the elevation of the pole, as upon the nature and circumstances of the winds that reign there.

'Tis a constant observation in these parts of the world, that northerly and north-easterly winds, at all times of the year, bring cold along with them; and commonly, if it be winter, produce frost. And here in *England*, I have sometimes wondered at the power of the winds to bring not only sudden frosts, but sudden thaws; when the frost was thought to have been settled. For during one of the most considerable seasons of frost and snow, that I have taken notice of in this country, I found the wind, for many days, to be southerly; unless it may be said that this southerly wind, was but the returning stream of the northern, which had blown for many days before; and might, by some obstacles and agents, be made to wheel about or recoil, hither, before it had lost its refrigerating corpuscles. And Captain *James* observed, that the wind blowing southerly at *Charlton* island, in the month of *August*, the weather was snowy and foggy; freezing their rigging, and making every thing so slippery, that they could scarce stand.

Prosper Alpinus attributes strange effects to the northerly wind in *Egypt*, as to cooling and refreshing the air, in spight of the violent heats that would, otherwise, be intolerable. And many in *Egypt*, he says, ascribe to the etesian winds, that almost miraculous ceasing of the plague at *Grand Cairo*.

Whence winds should have this power to change the constitution of the air, and, particularly, to bring cold along with them, is not easily determined. Other qualities, indeed, and even the heat observable in winds, may, generally, proceed from those of the places thro' which they pass, as we have already observed: and it may be further confirm'd by what *Acosta*, himself, saw in some parts of the *Indies*, viz. "that "iron gates were so rusted and consumed by a peculiar wind, that, upon "squeezing the metal between his fingers, it dissolv'd and crumbled "like parched straw." And this learned traveller, who seems to have taken

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taken peculiar notice of the wind, affords us ſeveral examples, to con- PHYSICS.
firm what we advance. " At a ſmall diſtance," ſays he, " many diver-
" ſities may be ſeen in the ſame wind; for example, the eaſt wind is,
" commonly very hot and troubleſome in *Spain*, but in *Murria*, it is
" the moſt cold and healthful, becauſe it paſſeth along the orchards
" and large champaigns which appear very freſh. But in *Carthagena*,
" which is not far from thence, the ſame wind is troubleſome and
" unwholeſome: and the ſouth wind," adds he, " is commonly rainy
" and boiſterous, tho' in that city wholeſome and pleaſant." And in his deſcription of *Peru*, he affirms, that the ſouth and ſouth-weſt winds are exceeding pleaſant in that country.

But tho' many other qualities of winds may be deduced from the nature and condition of the places along which they paſs; and tho' the heat, alſo, which *Proſper Alpinus* attributes to the ſoutherly winds in *Egypt*, may be, probably, aſcribed to the heated exhalations, and vapours they bring from the ſouthern and ſcorched regions they blow over; yet whence the great coldneſs of northern and eaſterly winds ſhould proceed, may well ſeem ſtrange to thoſe who will not admit of corpuſcles of cold. I ſhall, therefore, ſubjoin an experiment that I made, to give ſome light into this matter.

I cauſed a pretty large pair of ordinary bellows to be long kept in the room where we deſign'd to make our experiment, to receive the temperature of the air therein; then placing, upon a board, a flat-bottom'd weather-glaſs, furniſhed with a moveable drop of pendulous water, and blowing, at ſeveral times, with intermiſſions, upon the lower end of the glaſs, I found, that tho' the wind coming againſt my hand, felt manifeſtly cold, yet it did not cool the air included in the bubble, but rather a little warm'd it; as appear'd by a ſmall ſenſible aſcent of the pendulous drop, after the lower part of the glaſs was blown: upon which ſeem'd to proceed from ſome ſmall alteration towards warmth, that the air received by its ſhort ſtay in the bellows; for if by cloſely covering the clack, the air came into the bellows, wholly thro' the noſe thereof, whilſt held very near the bubble of the glaſs, that ſtream of wind coming from a part of the window where the air was a little cooler than that which was before blown out of the bellows, would not, as the other, make the pendulous drop riſe, but rather the contrary.

We then proceeded to ſhew, by experiment, that tho' a wind were only a ſtream of air, yet in its paſſage it might acquire a conſiderable coldneſs, diſtinct from what it has by virtue of its motion, tho' upon that ſcore, we ſee the air mov'd by a fan, or a pair of bellows may feel cold to our touch. Having inverted a ridge-tile, and half fill'd its cavity with a mixture of ice and ſalt, we plac'd the iron pipe of the bellows upon that mixture, and cover'd it with more of the ſame, that ſo the pipe being ſurrounded thereby, the air contain'd

PHYSICS. tain'd in it might be highly refrigerated; then blowing the bellows againſt my hand, the blaſt felt much colder, than what came out of the ſame bellows before the refrigerating mixture was applied. But for fear my ſenſe of feeling might deceive me, I caus'd a thermometer, made after the common manner, but with a more ſlender pipe, to be ſo plac'd, that the noſe of the bellows lay level with the bubble of the glaſs; and then blowing the refrigerated air of the bellows upon the globular part of the thermometer, the water in the cylindrical part and ſhank, manifeſtly aſcended, as is uſual upon the refrigeration of the included air; and as this aſcent of the liquor continued during three or four blaſts of the bellows, ſo upon the ceſſation of the artificial wind, it again ſubſided, by degrees, till by freſh blaſts it was again impelled up. Laſtly, having repeated this experiment, we drew back the noſe of the bellows, that the air to be now blown out, might paſs along the cavity forſaken by the iron pipe; when, the wind was manifeſtly more cold than before, and had a greater effect upon the thermometer, againſt which 'twas blown. And to ſatisfy my ſelf, that it was not the bare wind, whoſe operation upon the air included the ball of the weather-glaſs caus'd the liquor to aſcend, I mark'd the height it ſtood at, after we had, for a pretty while, blown upon it; and then, without removing the bellows, put ice and ſalt about the iron pipe of them; by which means the air afterwards blown thro' that pipe, was ſo cool'd in its paſſage, as to make the fluid very manifeſtly aſcend, even in a weather-glaſs, where quick-ſilver was us'd inſtead of water, or ſpirit of wine. And leſt the nearneſs of the frigorific mixture ſhou'd be ſuſpected to have caus'd this contraction of the included air, we ſometimes purpoſely intermitted the blaſts of the bellows, without removing the weather-glaſs; and tho' notwithſtanding that vicinity, the liquor wou'd begin a little to ſubſide, yet whenever the cold corpuſcles of the highly refrigerated air, were, by the playing of the bellows, brought anew, to touch in ſwarms, the globular part of the inſtrument, the mercury wou'd manifeſtly riſe. I find, however, that the ſeaſon of the year, and ſome other circumſtances, may conſiderably vary the experiment. For tho' I have here faithfully recited the phenomena of it, yet coming ſome months after, and in different weather, to repeat it, I was ſurpriz'd at the ſucceſs. For, blowing upon the ball of the ſeal'd weather-glaſs, I found, that if I continued to do this long and briſkly, the highly rectified ſpirit of wine wou'd ſometimes manifeſtly ſubſide.

However, this experiment duly proſecuted, may poſſibly afford ſtill farther light.

But I will not here pretend to determine, whether all cold winds muſt be neceſſarily made cold, by frigorific corpuſcles, properly ſo call'd; for I have ſometimes ſuſpected, that winds may be cold only by conſiſting of, or driving before them, thoſe higher parts of the air, that,

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by reaſon of the languid reflection of the ſun's rays in that upper region, are generally very cold; for it may be obſerv'd, that rains often greatly and ſuddenly refrigerate the lower air, when no winds but what the rain and clouds occaſion, attend them; as if they brought cold air along with them from that upper region; which both *Acoſta*, and one who has viſited far higher mountains than the *Alps*, affirm to be, in ſome places, exceedingly cold in hot climates, and hot ſeaſons of the year. But to leave this conjecture, Mr. *Wood* informs us, that "tho' in *England*, "moſt of the cold winds and weather proceeds from the ſea; and tho' "thoſe ſituations are counted moſt unwholſome that are near the coaſt; "it is otherwiſe in *New-England*." And having added as his reaſon, that "the north-eaſt wind coming from the ſea, produces warm wea-"ther, melting the ſnow, and thawing the grounds;" he ſubjoins "on-"ly the north-weſt wind paſſing over the land, is the cauſe of extreme "cold weather, being always accompanied with deep ſnows, bitter "froſts, *&c.*" To which we ſhall add this paſſage from Capt. *James*'s voyage. "The winds ſince we came hither, have been very variable "and inconſtant, and till within this fortnight, the ſoutherly wind "was coldeſt. The reaſon, I conceive to be, becauſe it blow'd from the "main-land, which was all cover'd with ſnow; and that the north winds "came out of the great bay, which hitherto was open." And laſtly, I have been aſſur'd, that in *Greenland* itſelf, the north-eaſt winds were colder than any other; which my relator aſcrib'd, in part, to the ſituation of the country; thoſe winds blowing over vaſt tracts of ice without any ſea, to mitigate the cold they communicate.

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XXII.

I come now to conſider thoſe effects of cold, that are not familiar but ſeem to have in them ſomething of wonderful.

Strange effects of cold.

As to the power of cold, either to contract the ſphere of activity of fire, or to hinder its uſual effects, the chief examples I have met with are recorded, by the *Dutch*, to have happen'd in *Nova Zembla*, and by Capt. *James*, when he winter'd in *Charlton* iſland. Theſe *Hollanders* ſpeak thus. "On the twentieth it prov'd fair and ſtill weather, the wind eaſter-"ly; but it was ſo cold, that when we had waſh'd and wrung our ſheets, "they preſently froze ſo ſtiff, that altho' we laid them before a "great fire, the ſide that was expos'd thereto was thaw'd, but the "other remain'd hard frozen." And again, "we were in great "fear, that if the extremity of the cold increas'd, we ſhou'd all "die there; for what fire ſoever we made, it wou'd not warm "us." Tho' Capt. *James* winter'd in a country many degrees more remote from the pole than *Nova Zembla*, yet he gives us this account of the power of the cold to oppoſe the action of fire. "The "cook's tubs wherein he water'd his meat, ſtanding about a yard from

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PHYSICS. " the fire, and which he all day long ply'd with ſnow-water, were in " the night ſeaſon firmly frozen to the bottom; and therefore he was ob- " liged to water his meat in a braſs kettle, cloſe adjoining to the fire: and " I have often found the ſide next the fire very warm, whilſt the other " remain'd frozen an inch thick."

This relation, compar'd with thoſe of the *Hollanders*, makes me the leſs wonder it ſhou'd be related to *Marcus Polus*, that there is a certain plain in *Tartary*, ſituated between ſome of the higheſt mountains in the world, " where if fire be kindled, it burns not ſo bright, nor proves ſo " effectual to boil any thing, as in other places."

Theſe relations of travellers, tho' to us who live in *England*, they cannot but ſeem ſtrange, yet I dare not reject them as incredible; becauſe ice and ſnow having been water before their congelation, muſt, in probability, owe their coldneſs to that which reign'd in the air ſo that if in any place, nature has either ſo plentifully ſtock'd the air itſelf with frigorific corpuſcles, or upon any other account rendred it as cold as ice, and ſnow are amongſt us; I know not why in more northern climates, where, perhaps, ſome ſaline exhalations ariſe from the earth and ſea, a coldneſs may not be diffus'd thro' the air, ſuperior to that which, by ſmall quantities of ice and ſalt, is at a ſmall diſtance producible here; yet this is ſo intenſe, that by pouring ſome water on a board, and placing a convenient veſſel thereon, we may with beaten ice, or ſnow and ſalt, and a little water, nimbly ſtirr'd together in that veſſel, make the mixture freeze the external water quite thro' it, to an exceſſive degree; and that too juſt by the fire.

How greatly the air is affected by cold, we have ſeen already, by the freezing of ſpittle, or water, barely in falling thro' it: and to give two or three remarkable inſtances of its effects upon fluids, 'tis ſaid, that on the 27th of *September*, it froze ſo hard, that as the *Dutch* in *Nova Zembla*, put their nails into their mouths, to be in a readineſs for driving, ice wou'd hang thereon; and when they took them out again the blood wou'd follow. And this is ſcarce more ſtrange than what is affirm'd by Dr. *Fletcher*, who ſpeaking of *Muſcovy* ſays, " if you there in the win- " ter hold a metalline veſſel in your hands in the open air, they will " ſtick faſt together, ſo that the ſkin will come off when you part them." Nay, in *Ruſſia*, and ſome other cold countries, if a man be abroad in the winter air with a cane, furniſh'd with a metalline head, and the tip of the tongue be applied to the metal, they will ſtick, and be as it were glew'd together; ſo that they cannot be ſever'd without great pain, and ſometimes not without leaving the ſkin of the tongue behind. And this has been affirm'd to me by eye-witneſſes of unqueſtionable credit. An ingenious phyſician, alſo, affirm'd to me upon trial, that the pummel of a ſword, expos'd to the winter air in *Moſcow*, wou'd ſtick to the tongue that touches it, and fetch off the ſkin, if forcibly and ſuddenly pull'd away.

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The reaſon of ſo odd a phenomenon, as far as I can conjecture, may be the great and ſudden loſs of agitation in the *Saliva*, and part of the tongue. Thus, if an ivory ball meet, in a direct line, with another of equal bigneſs, moving upon a billiard-table, 'twill communicate to it a part of its own motion, and retain the remainder; but if the latter were at reſt, the ball impell'd againſt it, will communicate almoſt all its motion thereto, and loſe as much itſelf; as appears by its remaining quieſcent in the place of the other. In like manner, the metalline head of the ſtick, by the intenſeneſs of the cold, may have its parts ſo depriv'd of motion, that when thoſe of the *Saliva* and tongue have communicated as much of their agitation as they can, there will not remain among thoſe three bodies a ſufficient degree of motion to keep the ſpittle fluid; which therefore being turn'd into ice, will ſtick to both the conſiſtent bodies, the tongue and the metal, and by this means faſten them together. In confirmation of this conjecture, I might add, there are ſome other phenomena explicable by the help of it. For inſtance, in very froſty mornings, the ice which ſticks to glaſs-windows, and often appears in the form of trees, or other odd figures, is vulgarly accounted for by ſuppoſing the cold produced them on the out-ſide of the glaſs, which, ſome fancy the vapours of the warm room penetrate. But 'tis plain, that this ice is formed within the room, as I have often obſerv'd, either by the thawing or ſcraping it off; ſo that it appears to be made of vapours floating in the air and chancing to paſs along the glaſs of the windows; which by the cold of the external air in froſty weather, loſing the natural agitation of its parts, theſe transferring ſo much of their motion to the glaſs, retain not enough to keep them fluid; the conſequence whereof is, they are turned into ice, which, in very cold countries, will be far thicker than in *England*; and accordingly, an acquaintance of mine aſſured me, he obſerv'd the ice on the in-ſide of the windows of ſome ſtows in *Ruſſia*, to be near an inch thick. And tho' *Macrobius* and other learned men, diſſallow ſalt-water to be congealable, yet the *Dutch* relate, that at *Nova Zembla*, even in the midſt of *September*, "it was froze two "inches thick." PHYSICS.

The effects of extreme cold upon the common earth, are very remarkable. *Olearius* relates, that in the year 1634, the cold was ſo bitter at *Moſcow*, that in the great market-place he ſaw a cleft many yards long, and a foot broad, occaſion'd by it: and the like has been confirm'd to me, by the *Czar*'s chief phyſician.

'Tis ſomewhat ſtrange, that both the violent heat of ſummer, and the extreme cold of winter, ſhou'd produce the like effects in the ground; but not having yet made the proper experiments, to ſhew from whence this phenomenon proceeds, I do not pretend to determine the cauſe thereof.

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PHYSICS. The *Dutch*, in their third voyage to *Nova Zembla*, tell us, that " when they had built a wooden houſe, and were going to ſhut themſelves up therein, for the winter, they made a great fire on the outſide, to thaw the ground, that they might place wood about the houſe to make it the cloſer; but it was all loſt labour: for the earth was ſo hard, and frozen ſo deep, that they cou'd not thaw it." *Martinius Cromerus*, in his *Polonia*, records, that " cold is ſometimes ſo violent there, that trees wither at the roots, and water pour'd from on high, turns to ice before it reaches to the ground; that the lakes, marſhes and rivers, are ſo frozen for two or three months in the winter, and ſometimes for five or ſix, that horſes and loaded carriages may freely and ſecurely paſs over them. And I my ſelf," ſays he, " have on the laſt day of *March*, paſs'd over the *Weiſſel* in *Maſovia*, upon the firm ice, with a coach and four horſes, and a retinue of horſemen."

After having ſeen ſome ſtrange effects of cold upon the ſeveral elements, we proceed to take notice of its power upon compounded bodies. But as we have already deliver'd its operation upon beer, ale, vinegar, oil, wine, *&c.* as alſo upon wood, bricks, ſtone, veſſels of glaſs, earth, pewter, iron and braſs, with many ſtrange effects of it upon other inanimate bodies; we ſhall here produce no more inſtances of that kind, but proceed to obſerve the effects of the ſame quality upon animals. We may, however, firſt intimate in general, that tho' many plants are preſerv'd by a moderate cold, yet it has been found, that moſt garden plants are deſtroy'd by exceſſive degrees thereof. Capt. *James* ſpeaking of the greateſt degree of cold, *viz.* that which he and his company felt in the woods of *Charlton* iſland, ſays, " it was ſo extreme as to be intolerable; no clothes were proof againſt it, no motion cou'd reſiſt it. It wou'd freeze the hair of our eye-lids, ſo that we cou'd not ſee; and I verily believe, it wou'd have ſtifled a man in a few hours time."

Olearius giving an account of the air of *Muſcovy*, and eſpecially of the capital city thereof, tells us, " the cold is there ſo violent, that no furs can prevent it; but that ſometimes men's noſes and ears, feet and hands, will be frozen and fall off;" he adds, " that in the year 1634, when he was there, they cou'd not go fifty paces without being benumb'd with cold, and endangering the loſs of ſome of their limbs."

Dr. *Fletcher* ſpeaking of the cold, that ſometimes happens in *Ruſſia*, affirms, that " not only travellers, but people in the very markets of their towns, are kill'd by it; ſo that many drop down dead in the ſtreets, and travellers are brought into the towns ſitting dead and ſtiff in their ſleds; and abundance loſe their noſes, the tips of their ears, and the balls of their cheeks, their toes, feet, *&c.* When the winter is very hard, the bears and wolves often iſſue by droves out of "

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" of the woods, driven by hunger, and enter the villages, tearing and PHYSICS.
" ravaging all they can find; ſo that the inhabitans are oblig'd to
" fly for their lives."

To deſcend now to the more particular phenomena of cold in the human body.

An old ſea-captain told me, that when he was in *Greenland*, his appetite grew ſo great, that he cou'd eat more in one day, than in a week or ten days here; and that accordingly, both he and others found themſelves ſtronger there, than in *England*, and more inclin'd to venery.

'Tis related of the *Hollanders* in *Nova Zembla*, that if they remain'd long in the open air, there aroſe bliſters upon their faces and ears: and Capt. *James* ſays, " the cold in the woods wou'd freeze our faces, or any " part of our fleſh that was bare."

The *Dutch* ſpeaking of the pains they took to dig away the ſnow, that cover'd the houſe, and choak'd up their door, ſay, " they were " forc'd to uſe great expedition, for they cou'd not long endure the " extreme cold air, tho' they wore foxes ſkins about their heads, and " double apparel upon their backs." Captain *James* farther relates, that in *Charlton* iſland he was oblig'd to cut the hair of his head ſhort, and ſhave away all that of his face, becauſe the iſicles wou'd otherwiſe faſten thereto, and make it intolerable. And he again ſays, that he and his companions having once been parted for a little while into two companies, " they all had their faces, hair and clothes, ſo fro- " zen over, that they cou'd not know each other by their habits, nor " even by their voices." And the ſame author gives this account of the death of the gunner of his ſhip, whom he calls a ſtrong-hearted man, who died before the end of *November*. " He had," ſays the Captain, " a cloſe boarded cabin in the gun-room, which was cloſe indeed, and " as many clothes on him as was convenient, and a pan with coals of fire " continually in his cabin; for all which warmth, his plaiſter wou'd " freeze at his wound, and the bottle of ſack at his head."

" The 11th of *December*," ſays the writer of the *Dutch* voyage to *Nova Zembla*, " was fair weather, the air clear, but very cold, for our " ſhoes froze as hard as horns upon our feet, and within ſide they " were white; ſo that we were forced to make great pattens, the up- " per part of ſheep-ſkins, which we put on over three or four pair " of ſocks, and ſo went in them to keep our feet warm; but the " clothes upon our backs were all over white with froſt. And," ſays Capt. *James*, " our bed-clothes wou'd be cover'd with hoar-froſt, which " lay not far from the fire."

We might add from *Gerat de Veer*, that " on the 26th of *December*, it " was foul weather, the wind at north-weſt, when it prov'd ſo cold " we cou'd not warm ourſelves, tho' we us'd all poſſible means, great " fires, ſtore of clothes, hot ſtones and billets applied upon our feet,

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PHYSICS. " and upon our bodies, as we lay in our cabins; but notwithſtanding " all this, our cabins were frozen in the morning."

A knowing and very credible perſon has related to me of the cold of *Ruſſia*, where he travell'd, particulars almoſt as ſtrange as thoſe I have mention'd from books: and a very learned traveller aſſures me, he met with a ſtrange operation of the inclemency of the air, upon multitudes of men at once, recorded in an approv'd hiſtory; *viz.* that, about the year 1498, an army of the *Turks* having made an incurſion into *Poland*, were upon their return, ſurprized with ſuch an extremity of cold and of ſnow in *November*, that out of the whole army, which conſiſted of 70000 men, 40000 periſh'd upon the ſpot.

Amongſt the many relations I have met with, of the fatal effects of cold in northern countries, I am ſurpriz'd, I cou'd not find any account of the change made in the internal parts of the bodies kill'd by it. But meeting with a deſcription of a *Poliſh* province, call'd *Ukrain*, of the ſame latitude with *Normandy*, and often ſubject to exceſſive cold, I find the author gives an account, not indeed of what I ſought for in him, but of two differing effects of cold upon the bodies of men. The firſt is, that ſometimes, when the natural heat proves ſtrong enough to protect the toes, cheeks, ears, and other parts, that are either more remote from the heart, or more tender, from a ſudden mortification; yet unleſs nature be aſſiſted either by good precautions or remedies, ſhe cannot hinder the cold from producing cancers in theſe parts, as painful as thoſe which are caus'd by a ſcalding and malignant humour; which ſhew'd me, ſays our author, that cold has as great a power to deſtroy things, as fire to conſume them. He adds, that the beginning of theſe cancerous ſores is ſo ſmall, that what produces the pain, ſcarce equals the bigneſs of a pea; and yet in few days or hours it ſpreads ſo, as to deſtroy the whole part it invades: and this he confirms by the example of two perſons of his acquaintance, who thus immediately loſt the characteriſtics of their ſex. As to thoſe who are kill'd with cold, our author ſays, they periſh differently. For ſome, not being ſufficiently fortified againſt the cold by their own internal heat, nor competently arm'd againſt it by furs, inunctions, and other external means; after having their hands and feet firſt ſeized, till they grow paſt feeling it, the reſt of their bodies is ſo invaded, that they are taken with a drowſineſs, that gives them an extreme propenſity to ſleep, which if indulg'd, they awake no more, but die inſenſibly. And from this kind of death, our author adds, he was ſeveral times ſnatch'd by his ſervants, who were more accuſtomed to the cold than he, and ſeaſonably forc'd to awake out of thoſe drowzineſſes, which they knew to be dangerous. And indeed, that death by cold is ſometimes indolent, the relations of ſome intelligent acquaintance of mine, who have been in exceeding cold countries, confirm.

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But the other way whereby cold deſtroys a man, is the moſt remarkable. He tells us, that ſometimes the cold ſeizes the reins, and all about the waiſt, eſpecially horſemen, underneath the armour of the back and breaſt; and ſtrikes into thoſe parts ſo forcibly, that it freezes the *abdomen* and *viſcera*; ſo that tho' they have keen appetites, they cannot digeſt or retain the lighteſt aliment, but preſently reject it by vomit, with unſpeakable gripings and pains; and ſo continually complaining of their condition, and ſometimes crying out, as if their bowels were tearing out, they end their miſerable lives almoſt in madneſs and deſpair. Having ſeen ſome of theſe departed wretches open'd, he ſays, they found the greateſt part of their *viſcera* black, burn'd up, and as it were glew'd together; whence he thinks it probable, that as their bowels came to be gangrenated, they were forc'd to thoſe complaints and exclamations; and we may add, that, probably, upon the ſame cauſe depended thoſe continual vomitings of what they eat and drank; the gangrene of the guts hindering the paſſage of the excrements downwards, as it often happens in the true *Iliaca Paſſio*; and the periſtaltic, or the uſual motion of the guts being inverted, as it alſo frequently happens in the ſame diſeaſe. Anatomiſts and phyſicians, no doubt, will think this account very imperfect; but 'tis the beſt, and, indeed, the only one, I have hitherto met with of this diſtemper; tho' I cou'd wiſh it had been much more full and particular, and that he had alſo open'd thoſe animals, and eſpecially their brains, which he mentions to have been kill'd ſuddenly, and without pain, by cold. For, ſuch informations, (the want whereof, as far as our climate wou'd permit, I have had thoughts of ſupplying by experiments upon other animals,) wou'd perhaps ſatisfy me in a conjecture, countenanc'd by ſeveral trials upon vegetables and animals after death, as to the cauſe of mortifications produced by exceſſive cold. PHYSICS.

What effects may be produc'd by violent cold upon other animals, I ſcarce find mention'd by any writers I have met with. The author, indeed, lately quoted M. *de Beauplan*, tells us, in general, that the cold in *Ukrain* is ſometimes ſo great, as to be ſcarce ſupportable by horſes, and ſome other cattle. He alſo mentions a familiar four-footed animal, call'd *Boback*, ſaid to be peculiar to thoſe parts, that hides itſelf under ground in winter. A *Poliſh* nobleman told me, that when he was in that province, he had one of them preſented him as a rarity, which ſome of the *Poles*, chancing to dig in a retired place, were ſurpriz'd to find: and tho' this creature was frozen ſo ſtiff, that they thought it to be ſtark dead; yet when they came to flea it for its ſkin, it was awaken'd by pain, and recover'd itſelf.

That ſome other animals may be frozen 'till they are ſtiff, and yet recover, we ſhall ſee hereafter. 'Tis a tradition among thoſe who travel into northern climates, that both birds and wild beaſts, are in icy and ſnowy countries, ordinarily turn'd white, in the winter, by the coldneſs of thoſe parts. This account I dare neither admit as true univer-

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PHYSICS. univerſally, nor reject as utterly falſe. For, not now to enquire into the cauſe of this whiteneſs, I find, by the voyages that I have peruſed, that ſailors often mention their meeting with numbers of white bears and foxes in *Nova Zembla*, and other very northern regions; and alſo, ſometimes, with herds of white deer: and in the *Alps*, which are always covered with ſnow, credible authors mention, their having ſeen white patridges. And I remember, when I was in *Savoy*, and the countries adjoining thereto, where the tops of the mountains are almoſt perpetually covered with ſnow, frequent mention was made to me of a certain white kind of pheaſants to be met with in the upper parts of the mountains, which were accounted very delicious. But on the other ſide, the ſame ſailors, treating even of the coldeſt climates, ſeem to diſtinguiſh the white bears from others of thoſe parts. And 'tis from very northern countries, that we uſually receive dark coloured furs, and the ſkins of black foxes, as well as white ones. But as for the herds of white deer, their colour may proceed from ſeminal impreſſions; ſince here, in *England*, I have ſeen white ones. And tho' *Greenland* be ſome degrees nearer the pole than *Nova Zembla*, yet I have ſeen a live deer brought from thence, whoſe ſkin was not white, but rather of a kind of dun; and his coat might well have paſs'd for a fur. Yet theſe two particulars ſeem to favour the efficacy of cold; the one, that in ſeveral cold countries, as particularly in *Greenland* and *Livonia*, even modern deſcribers of them affirm hares will turn white in winter, and return to their native grey colour in ſummer; the other, that tho' *Charlton* iſland differ not one degree in latitude from *London*, yet Captain *James* takes notice of foxes there, that were pied, black and white; and alſo of white patridges.

The *Swediſh* ambaſſadors aſſured me, that in *Muſcovy*, and ſome other northern countries, the hares are of the ſame colour with ours in ſummer, but ſnow white in winter; and that they begin to change colour in autumn, and to recover it in the ſpring. The elder of them, Monſieur *Coyet*, aſſured me, he had himſelf obſerved the thing; and the ſame was, likewiſe, affirmed by the *Swediſh* reſident then preſent; who farther added, that on the borders of *Muſcovy*, he had ſeen numbers of milk white patridges in winter; and they all three agreed, that ſquirrels, which, in ſummer, are of the uſual colour with ours, do, in the winter, turn grey, and recover their brown colour the following ſummer. They were pleaſed, alſo, to ſend me word by an ingenious gentleman, ſon to Monſieur *Coyet*, that on one ſide of the river *Duna*, which divides *Livonia* and *Muſcovy*, the hares are of the ordinary colour, but on the other ſide white; ſo that when the hunts-men meet with any white ones, on that ſide the river, ſuppoſed peculiar to the other, they call them deſerters.

An old ſea-captain told me, that the white bears in or about *Greenland*, notwithſtanding the coldneſs of the climate, have an excellent noſe; and that ſometimes, when the fiſher-men had diſmiſſed the carcaſs of

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more, whence it could not be feen, theſe animals would ſtand as near the water as they could, and raiſing themſelves on their hind-legs, loudly ſnuff in the air, and with the two paws of their fore-legs, as with fans, drive it as it were againſt their ſnouts; and when they were (as my relator ſuppoſed) ſatisfied, whence the odour came, they would caſt themſelves into the ſea, and ſwim directly towards the whale, as my relator and others obſerve, who had ſometimes the curioſity to row, at a diſtance, after them; to ſee whether their noſes would ſerve them for guides, when their eyes could not. He ſaw no other bears in thoſe parts but white ones.

An inquiſitive perſon told me, that having reſided for ſome time in *Pruſſia*, he had, more than once or twice, in different places, obſerved, as others in his company alſo did, that the fiſher-men, in breaking the ice of ponds which had been long frozen, and taking out thence conſiderable maſſes of it, ſeveral times found many ſwallows in them, ſo incloſed in the ice, as not to be got out but by breaking or thawing it. He farther ſaid, that when theſe lumps of ice came to be thaw'd in the ſtoves, the ſwallows, which lay ſeemingly dead before, would revive, and perhaps fly about the room, but did not long ſurvive their recovery out of their inſenſible ſtate; ſome dying again in few hours, others the next day, or perhaps on the third; but few or none, that he obſerved, lived beyond the fourth or fifth. This, as my relator judg'd, happened thro' their want of appetite; but, I believe, it proceeded principally from their want of flies and proper animals to feed on, which they could not obtain in the winter.

XXIII.

Experiments upon the weight of bodies, frozen and unfrozen.

Since many ingenious men aſſert, that water is turned into ice by the introduction of frigorific corpuſcles, we thought fit to try whether a liquor, by its increaſe of weight when frozen, would betray them. And the firſt experiments we made to diſcover this were with eggs.

1. We placed an exact balance in a frame, and into one ſcale thereof put two eggs, and counterpoiſed them with braſs weights, then ſuffered all thus to continue, during a very ſharp night in a turret; and coming the next morning to view them, we found the eggs grown lighter by very near four grains: we afterwards repeated this experiment twice or thrice; but having been diverted from regiſtring the events, I dare only ſay, that ſome of the circumſtances ſeem'd very odd and uncertain; and that I deſiſted from proſecuting it, becauſe an increaſe of weight in eggs, thus expoſed, was hardly to be hoped for, ſince part of the more ſubtile and ſpirituous corpuſcles they contain, continually get away thro' the pores of the ſkin and ſhell: which ſeems to be the reaſon why eggs long kept, have uſually within the ſhell, a conſiderable cavity; ſo that tho' the frigorific atoms ſhould, by their ingreſs, here add a ſmall weight, yet that would not,

PHYSICS. unleſs perhaps in the very juncture when the congelation is firſt actually made, be taken notice of.

2. And for farther ſatisfaction in this matter, we carefully counterpoiſed four hen-eggs in a good pair of ſcales ſuſpended at a frame, and ſuffering them to continue for a pretty while, we obſerved, that tho' it were winter, and tho' the room made choice of was deſtitute of a chimney, yet that ſcale wherein the eggs lay, grew manifeſtly lighter, ſo that it was requiſite, from time to time, to take a grain out of the oppoſite ſcale, to reduce the balance to an equilibrium; and by this means, we found the eggs, after ſome time, to have loſt eight grains of their former weight; but how much more they would loſe, we could not ſtay to diſcover.

3. I endeavoured, alſo, to ſatisfy my ſelf, whether eggs, when once actually frozen, and kept in a pair of nice ſcales faſtened to a frame, in ſome quiet place that was well fenced from the ſun, would, by the cold of the air, in freezing weather, continue for any conſiderable time without a ſenſible diminution of their weight; but an unexpected thaw hindred us from ſeeing the ſucceſs of what we deſign'd of this nature, both as to eggs and ſome other bodies. But if the experiment were very carefully made upon a competent variety of them, eſpecially upon camphire and ſome other very exhalable bodies; it might poſſibly aſſiſt us to gueſs what intereſt the cold has in the ſuppreſſion, or exhalation of their effluvia.

4. But to return, a ſingle vial of water ſealed up, wiped dry, and weighing four ounces four drams and a half when froze by ice and ſalt, loſt by being thaw'd ſomewhat more than a grain.

5. We took a thin vial furniſhed with a long neck, which at the flame of a lamp, was drawn gradually ſlender, ſo that being very narrow at the top, it might the more readily be ſealed; this we filled with water, allowing room for its expanding upon glaciation, and placed it in a mixture of ſnow and ſalt; when the glaſs appeared nearly full of ice, it was taken out immediately, ſeal'd hermetically, and weigh'd in a pair of very good ſcales; whereby we found the whole amount to ſix ounces and half a grain, tho' ſome of the ice began to thaw in the operation: the vial being thus removed, and ſuffered to ſtand alone for two or three hours, the ice was vaniſhed; when we again put the containing glaſs, in the ſame ſcales, and found that it weighed rather a little more than before; but this not amounting to half a grain, it might well be attributed to ſome difference in the weights and grains themſelves, or to ſome unheeded moiſture that might adhere to the vial.

6. We placed another very thin vial of water, ſealed as the former, that weighed four ounces, two drams, forty one grains, in a mixture of ſnow and ſalt; thereby freezing it warily, to prevent its breaking; then we removed it into the ſame ſcales, and found it to weigh either juſt as before, or, if there were any difference, to have loſt a quarter of a grain. Being ſuffered to thaw, we placed it in the ſcale again, and

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and found its weight the ſame when frozen, tho' the weights were numerically the ſame, and about $\frac{1}{4}$ of a grain would turn the ſcales. I was careful this laſt time to wipe the outſide of the glaſs with a linen cloth, becauſe I had obſerv'd, if ice be haſtily thaw'd, it will there produce a dew. PHYSICS.

Captain *James* gives us a particular in his voyage, which, if it had been circumſtantially ſet down, might prove of moment in regard to the weight of bodies frozen and unfrozen. "We hoiſted our beer and cyder," ſays he, "and made a raft of them, faſtening them to our ſhore-anchor; they both ſunk preſently to the ground; which was nothing "ſtrange to us, becauſe any wood or pipe-ſtaves, that had lain under the "ice all winter, would ſink down as ſoon as ever they were heav'd over "board."

7. I was, alſo, deſirous to ſee whether any difference, as to weight, would be produced by freezing and thawing iron, ſtone, wood, or the like ſolid and permanent bodies, which I intended to have exactly weigh'd before and after they were expoſed to the air in froſty weather; and again, after the froſt was gone; and this againſt counterpoiſes, not expoſed to ſo great a degree of cold. And tho' we were prevented from bringing the matter to ſuch an iſſue as we deſired; yet this kind of experiments ſeems not irrational; ſince its highly probable, that even ſtones and metals ſuffer a change of texture by the action of ſome degrees of cold. And I remember to have made ſeveral experiments as to the weight of ſome metals and ſtones, both before and after they had been long expoſed to a more vehement cold than wou'd have ſufficed to turn water into ice, and alſo after they had been left expoſed to a warm air; tho' the paper in which we regiſtred the events of theſe trials having been miſlayed, I dare not charge my memory with the particulars; but if I miſtake not, one or two ſtones increaſed their weight, by being buried in our frigorific mixture; which may be imputed to ſome particles of the ice reſolved into water, by the ſalt imbibed into the pores thereof. For having procured an experiment to be made by an ingenious perſon, upon a ſtone hard enough to bear a good poliſh; he inform'd me, that the ſtone, by being kept a while in water, tho' it was afterward wiped dry, diſcovered a manifeſt increaſe of weight. And in confirmation of my conjecture, I might add, that from a ſort of ſtones, of a texture cloſe enough to bear a poliſh, I obtained, by diſtillation, a conſiderable quantity of an almoſt inſipid liquor, which I ſuſpected to be, chiefly, water ſoaked into the ſtone. But ſuch trials as theſe, with others of the like kind, we leave to be farther proſecuted. However, thoſe we made in ſealed vials, were managed with accuracy; and ſome of the reſt were deſigned to ſatisfy others rather than our ſelves; for ſhould an additional weight be found in frozen bodies, yet how do we hence know that the atoms of cold are either heavy or light, any more than the effluvia of magnetic and electrical bodies?

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PHYSICS. 8. The experiments here delivered, may, perhaps, keep men from being miſled by the contrary accounts, which I find to have been given of the weight of ice and water, by no obſcure writers. Thus *Helmont*, for inſtance, dogmatically tells us, that if a large glaſs-veſſel, filled with pieces of ice, be hermetically ſealed and balanced in a pair of ſcales, we ſhall find the thaw'd liquor weigh almoſt an eighth part more than the ice. Tho' we have already manifeſted the falſity hereof, yet for further confirmation, we ſeveral times, on purpoſe, weighed ice frozen and thaw'd, without finding any reaſon to doubt that *Helmont* was miſtaken; and particularly having filled a wide-mouth'd glaſs with ſolid fragments of ice, both together amounting to a pound weight, I whelm'd over the mouth of it, another flat-bottom'd glaſs, ſo that if any vapours ſhould aſcend, they might be condenſed into drops; this ice being thaw'd in a warm room, no drops appear'd on the inſide of the inverted glaſs; when the other being put into the ſame ſcale, appear'd almoſt exactly of the ſame weight as before; tho' the ice alone, that had been reſolved, amounting to much above eight ounces, ought, according to *Helmont*'s proportion, to have been augmented by a whole ounce at leaſt. And I make no doubt, that if the experiment had been tried with a greater quantity of ice, the event would have been very little, if at all, different. But I purpoſely choſe to make my trials in no great quantities of matter, becauſe 'tis very difficult to provide ſcales ſtrong enough to weigh them without being injured; and yet prove accurate enough to diſcover ſuch ſmall differences as are fit to be taken notice of in ſuch experiments. Miſtakes in theſe ſtatical trials may eaſily happen, unleſs great care be uſed. When open veſſels are made choice of to freeze water in, 'tis no wonder that the ice weighs leſs than the fluid; becauſe ſome of its parts will then fly away in congelation. Thus a porringer of water, ſet to freeze in the open air, I once obſerved to loſe fifty grains, and another ſixty; but making the like trial in a cloſe pewter pot, we found not the difference of a grain between the ice and the water, into which it was diſſolved. But that even ice, as well as water, may exhale in froſty weather, is prov'd by this experiment. Having placed ſeveral lumps of ſolid ice in a porringer, which together weighed a pound, and expoſed them in the ſame ſcales wherein they were weighed, to the free air of a very froſty night, we found the ice had loſt, next morning, twenty four grains of its weight: the weather continuing exceſſive cold, we kept the ice out of the ſun, in the ſame ſcales all day, and a large part of the following night, and then, weighing it the ſecond time, found that the whole decreaſe of weight amounted to two drams, five grains, tho' the weight of the ice, without the porringer, were but about ſeven ounces. And when we had kept about thirteen ounces of ice expoſed to the air in a very froſty night, it had loſt, the next morning, above two drams of its former weight.

9. The like experiment we made with ſnow as follows.

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Four ounces of ſnow, made up into a lump, and counterpoiſed in a pair of good ſcales, were expoſed in a froſty night, after eleven a-clock, without being taken out of the balance; the next morning between nine and ten, there appeared a decreaſe of twenty-nine or thirty grains, which ſeem'd to have evaporated from the ſnow it ſelf; for tho' a ſmall portion of it were melted in the ſcale, yet that amounted not to eight grains, which was not a third of the weight the ſnow-ball had loſt. But ſuppoſing the decreaſe would be greater, if the ſnow had a larger ſuperficies in proportion to the bulk thereof, I cauſed the following trial to be made. Two ounces of ſnow, made up into a flat cake, being expoſed all night, which was froſty, in the balance; there appeared, next morning, about eight a-clock, to have been loſt fifty-five grains, tho' no water was found in the ſcale; and about two hours after, the decreaſe was found to be about ſixty-three grains, none of the ſnow ſtill appearing to have melted in the ſcale*.

XXIV.

Promiſcuous experiments and obſervations upon cold.

I have at ſeveral times made different experiments to diſcover whether congelation would, by conſtringing the pores of bodies, vitiating their texture, or arreſting the motion of their parts, hinder them from emitting thoſe effluvia that we call odours.

1. Having in the months of *December* and *January*, whilſt the weather was froſty, gathered different ſorts of flowers, I could ſcarce perceive any ſmell therein; indeed, moſt of them were flaggy, and ſeemed ready to wither: but a primroſe, that was vigorous and freſh in its kind, had an odour that was manifeſtly ſweet and genuine.

I put, alſo, about an ounce of roſe-water into a ſmall vial, and after having ſmelt thereto, it was expoſed to freeze in the open air; and when it began to freeze, I ſmelt to it again; but found the perfume ſcarce

* M. *Gauteron* obſerved, during the great froſt at *Montpellier*, in the year 1708. that liquids evaporated much faſter than when the air was temperate. An ounce of water expoſed all night to freeze in a *China* veſſel two inches in diameter, had loſt in the morning twenty four grains; and after it was thaw'd, the water wanted twelve grains of its weight; tho' he was exceeding cautious to prevent a ſecond evaporation. Common water, oil of nuts, oil of turpentine, ſpirit of wine, oil-olive, and quick-ſilver, being expoſed after the ſame manner, and in the ſame quantity, the water preſently froze, and loſt ſix grains in an hour's time; the oil of nuts eight grains, the ſpirit of wine and oil of turpentine, each of them twelve grains in an hour; but the oil-olive and the mercury, appeared to have rather increaſed in their weight. Next morning the frozen water had loſt thirty-ſix grains; the oil of nuts, which remain'd unfrozen, forty grains; the ſpirit of wine and oil of turpentine, which alſo were not frozen, fifty-four grains each; but the mercury and oil-olive, continued nearly as they were. This gentleman found even the hardeſt ice evaporate ſo faſt, that in twenty-four hours it loſt about one hundred grains. And in the coldeſt night of this froſt, which he ſays was the moſt extreme, that had ever been felt in that country, the liquor of a common thermometer, being wholly reduced into the ball, the water loſt forty-eight grains, the oil of nuts fifty-four, and the oil of turpentine and ſpirit of wine each ſeventy-two grains. *Memoir. de l'Academ.* A. 1709. p. 584.—588.

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PHYSICS. at all abated; and laſtly, having ſuffered it to continue in the air that was then very ſharp, till quite congealed, the ice was not deſtitute of a grateful and genuine ſcent, tho' it ſeem'd ſomewhat faint; and even after the ice was again reduced to water, the fragrancy appeared conſiderable.

But care muſt be had in trials of this nature, to make an early eſtimate; for if too much time be ſpent herein, there is danger that the warmth of one's breath and face may relax the pores, or thaw the ſurface of the ice, and both free and excite the ſcented corpuſcles; whence, inſtead of ice, a liquor would be ſmelt to. Thus having procured ſome rain-water that had been kept in a tub, till it ſtunk ſo ſtrongly, that I could hardly endure it near my noſe, I cauſed a porringer full of it to be expoſed all night to a very ſharp air, and examining it next morning, when it was all turn'd into ice, neither I, nor others to whom it was offered, could perceive any ſtink at all in it; but having in another place repeated the experiment with as ſtinking water, when the porringer was the next morning brought to my bedſide, I found it ſtink abominably; for the warmth of the room had thaw'd the ſuperficial parts of the ice: but expoſing the veſſel with that liquor in it to the cold air again, an ice was produced that we found perfectly inodorous. And I remember that one of theſe parcels of ice being thawed, it ſeemed to be leſs fetid than before it had been frozen. And if I had not been diverted, I ſhould have tried whether this ice, that did not emit odours, would, like other ice, afford effluvia diſcoverable by the ballance; for whether it loſt of its weight or not, the event might afford a conſiderable hint.

2. We alſo attempted to diſcover the effect of congelation upon ſeveral other qualities; not only thoſe that are reputed manifeſt, as colours and taſtes; the latter whereof we ſometimes found to be conſiderably changed for the worſe in fleſh; but alſo thoſe that are uſually term'd occult; particularly, I had a mind to ſee whether the purging faculty of cathartics, would be advanced, impaired, or deſtroyed thereby: and for this purpoſe, I cauſed ſeveral purging liquors to be expoſed to the cold, ſome of a more mild, and others of a briſker nature, in the forms of ſyrup, decoction, infuſion, *&c.* but for want of opportunity to try, upon the bodies of animals, what change the cold had made in them, I was unable to ſatisfy my ſelf herein: only, as in ſome of theſe trials, I made uſe of purgative liquors prepared by fermentation, I ſhall add, that fermentation is ſo noble and important a ſubject, that the influence of cold upon it deſerves a particular inquiry.

That this influence may be very conſiderable, ſeems probable to me from having obſerved, upon trial, that raiſins and water did not, in many days, whilſt the weather continued very froſty, ſo much as begin to ferment, tho' the water were kept fluid; and that beer will continue

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tinue new, as it were, and unfit for drinking, much longer than could readily be ſuſpected, if very froſty weather happen before it has finiſhed its fermentation. And an experienced perſon aſſured me, that ſuch liquor would not ſometimes in five or ſix weeks of very froſty weather, be brought to ſuch a degree of ripeneſs, as one week of warm and friendly weather would give it. Nay, if I am rightly inform'd, the way to keep wine in the ſtate of muſt, is to take the juice of grapes newly preſſed, tun it up before it begins to work, and let down the veſſel, very carefully cloſed, to the bottom of ſome deep well or river, for ſix or eight weeks; during which time, the liquor will be ſo well ſettled, in its accuſtomed conſtitution, that it may afterwards be kept in almoſt the ſame ſtate, and for ſeveral months continue its ſweetneſs. PHYSICS.

3. Tho' the ſchools define cold by the property they ſuppoſe it has to unite heterogeneous and homogeneous ſubſtances; I attempted to make ſome ſeparations in bodies by the force of it. For if it holds true in this climate, which has been obſerved in more northern regions, that a very ſtrong ſpirit and a phlegm are obtainable from beer and wine by congelation, it ſeems probable, that in ſeveral other liquors, the wateriſh part will begin to freeze before the more ſpirituous and ſaline ones; and if ſo, we may be aſſiſted to make ſome ſeparations as well by cold as by heat, and rectify ſome liquors by congelation, as well as by diſtillation: but I doubt whether the ordinary froſts of this country afford a degree of cold, capable of making ſuch diviſions and ſeparations in bodies as have been obſerved in the more northern climates. However, having purpoſely hung out a glaſs-bottle of beer, in an extraordinary ſharp night, I found, the next morning, that the greateſt part of the liquor was turned into ice, while there remained at the bottom an uncongealed part, which to me, and others, ſeemed ſtronger than the beer, and was, at leaſt, manifeſtly ſtronger than the thaw'd ice, which yielded a ſpiritleſs liquor. But in ſome other trials my ſucceſs was not ſo conſiderable. For having put one part of highly rectified ſpirit of wine, and about five or ſix parts of common water, in a round glaſs plac'd in ice and ſalt; tho' the mixture was in great part turned into ice; yet I could not perceive that the two liquors were accurately ſeparated from one another; tho' the ſpirit of wine employed, was before-hand deeply tinged with cochineal; and therefore I the leſs wonder, that in claret, I could not make any exact ſeparation of the red and the colourleſs parts. But, I remember, ſpirit of vinegar, being expoſed to the cold in a large glaſs veſſel, a conſiderable part was turned into ice; which, by ſwimming, ſhew'd it ſelf to be lighter than the fluid. The froſt once ſeemed to have promoted a ſeparation of cream; and another time, there ſeemed to be a different ſeparation made in the parts of milk, by congelation; yet for want of leiſure to proſecute ſuch trials, they proved unſatisfactory; as did alſo ſome attempts of the like nature, made upon blood by freezing it.

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PHYSICS. it. But notwithſtanding theſe diſcouragements, I reſolved to try what I could do by this means upon brine, in order to free it from its phlegm, which might prove an advantageous experiment. For 'tis eſteemed one of the beſt methods to ſave the charge of fewel in making ſalt, to run their water thro' large bundles of bruſh-wood, that being thereby ſpread into a great ſurface, ſome of the pure aqueous parts may exhale away. Diſſolving, therefore, one part of common ſalt in forty-four times its weight of common water, that it might be reduc'd to the degree of ſaltneſs, that has been by ſeveral writers obſerv'd in the water of our neighbouring ſeas; and having likewiſe caus'd another much ſtronger brine to be made, to bring it near that of many of our ſalt-ſprings; we expos'd theſe ſolutions to the congealing cold of the air in froſty weather, when the latter, being too ſtrongly impregnated with the ſalt, continued ſome days and nights wholly uncongeal'd; but the weaker ſolution being expos'd in a ſhallow and wide-mouth'd veſſel, the large ſuperficies contiguous to the air, afforded us a cake of ice, which being taken off, and the reſt of the liquor expos'd again to the air in the ſame veſſel, we obtain'd a ſecond cake; and taking the remainder, which ſeem'd to be indiſpos'd to congeal farther, we found, by comparing it with what was afforded by the firſt cake of the ice permitted to thaw, a manifeſt difference; this ſcarce taſting ſo much as brackiſh, whilſt the liquor that continued uncongeal'd was conſiderably ſalt. And by examining theſe two liquors hydroſtatically, the difference between them alſo appear'd conſiderable; but this not being done with accuracy, I cou'd make no eſtimate of the advantage, that might ariſe from the operation of cold, towards freeing the brine from its ſuperfluous moiſture. I had not here a ſufficient quantity of ice to ſatisfy me, whether its little brackiſhneſs proceed from ſome ſaline corpuſcles, that concurr'd to conſtitute the ice itſelf, or only adhered to the lower part of it, among other particles of the liquor that remain'd uncongeal'd. 'Twere not perhaps amiſs to try, whether, in very large veſſels, this experiment, promoted by ſome expedients that practice will ſuggeſt, may not, in ſome ſeaſons and places, be turn'd to advantage.

4. I took ſeveral vegetable ſubſtances, of different kinds, as turneps, carrots, beets, apples, and tender wood, freſh cut from growing trees; as alſo many animal ſubſtances, muſculous fleſh, livers, brains, eyes, tongues, *&c.* and expos'd them to a very ſharp cold, that they might be thoroughly frozen. One of the chief things I propos'd to myſelf in this attempt was, to try how far I cou'd, by congelation, diſcover the texture of animals and plants unregarded by anatomiſts; and which cou'd ſcarce otherwiſe be render'd viſible. And accordingly, I found that in many ſucculent bodies, both vegetable and animal, the ſap or juice that was ſo diſpers'd among the other parts, and divided

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might, by congelation, be both discern'd and separated from the rest. For in several plants, I obſerv'd the alimental juice to be congeal'd into vaſt multitudes of diſtinct corpuſcles of ice, ſome of which, when the bodies were tranſverſly cut, and left a while in the open air, might be ſcrap'd off from the ſuperficies of the body, whereon it wou'd after a while appear in the form of an efflorescence, almoſt like meal: but in others, I took a better courſe; for, by warily compreſſing the frozen bodies, I cou'd preſently make the icy corpuſcles ſtart in vaſt numbers out of their little pores; and tho' ſome of theſe were ſo minute as to require an ordinary magnifying-glaſs, yet in other bodies, and eſpecially in carrots and beets, the icy corpuſcles were big enough to be diſtinctly and ſeparately view'd; ſo that I rightly conjectur'd both the figures and ſizes of theſe little pieces of ice, might be gueſs'd at by the ſhape and magnitude of the pores left in the more ſtable part, or parenchyma of the root. But in making an eſtimate of theſe cavities, as well as in diſcovering the order wherein they are ranged, I found it uſeful to cut the frozen roots ſometimes lengthwiſe, and ſometimes a-croſs. For by that means there wou'd appear in large carrots, for example, a great diſparity in the order of the pores, which, when the root was divided by a plain parallel to the baſis, ſeem'd plac'd in almoſt ſtreight lines, tending from the centre to the circumference; but if it were ſlit from one end to the other, the icy corpuſcles and pores wou'd ſeem rang'd in a very different order.

I muſt not here omit, that as I many years ſince made an experiment of freezing the eyes of oxen, and other animals, whereby the ſoft and fluid humours of that admirable organ may be ſo harden'd, as to become tractable to the meaner anatomiſts; ſo on this occaſion I apply'd that experiment to the brains of animals, which tho' too ſoft to be eaſily diſſected, may by congelation be made every way manageable. In diſſecting the brain thus harden'd, it ſometimes ſeem'd that the knife cut thro' multitudes of icy corpuſcles; the ſubſtance of it appear'd alſo to the eye to be ſtuff'd with them, and the ventricles to harbour pieces of ice, and were perhaps fill'd up with them. And methinks the manifeſt difference of texture that there is, between the white and yolk of a thoroughly frozen egg; betwixt the cryſtalline, aqueous and the vitreous humours of the eye, wherein by congelation the cryſtalline alone loſes its tranſparency, but acquires no conſpicuous ice, whilſt the other are full of diaphanous ice; with the like diſparities, may afford improvable hints to ſagacious anatomiſts.

We formerly obſerv'd, that congelation commonly ſpoils or impairs eggs, apples, fleſh, &c. let us ſee now in what caſes we may give a mechanical account of this phenomenon. Tho' the immerſion of fro-

dice, than if they were lastly thaw'd by the fire, or spontaneously in the air; yet there have been complaints made, that notwithstanding this expedient, several bodies are much the worse for being once frozen thoroughly. Since then I have shewn, that in many solid bodies the alimental juice is by congelation turn'd into ice, and have evinc'd that water, and aqueous liquors, are expanded by congelation; I see not why the innumerable icy corpuscles, into which the alimental juice is turn'd by the frost, being each of them expanded proportionably to their respective magnitudes, may not only prejudice the whole, by having their own constitution impair'd, as has been formerly observ'd in alicant and other vinous liquors; but also upon their expansion crush in some places, and distend in others, the more stable parts, in whose cavities they were harbour'd, and thereby so vitiate their texture, as to impair some of their qualities, and dispose the composition to corruption.

How greatly contusion may prejudice tender bodies, and accelerate putrefaction, is evident in many fruits, especially the more tender ones, which having been bruis'd, quickly begin to rot in the injured parts; and 'tis agreeable to what has been formerly shewn, that in congelation there happens innumerable little contusions made by the fluid parts, harden'd and expanded by the frost, of more stable ones, every where intercepted between them; and tho' these icy corpuscles be small, yet the sides of the firm matter that separate them, and which they endeavour to stretch or crush, are often proportionably thin. And we have seen not only that eggs will burst by having their alimental juice frozen, but that both shingles and stones may have their texture spoil'd, by the congelation of the mineral sap, that is, in exceeding minute and insensible particles, dispers'd thro' them. And the violation of the texture of plants, herbs and animals, by the expansion of the aqueous and juicy particles, which abound there, will seem less surprizing, if it be remember'd, that a few ounces of water congeal'd, will burst thro' glass, pewter, brass, or iron.

Whilst I was upon these trials, I had also a desire to know, whether by freezing animals to death, any such change in the qualities or structure of their parts cou'd be discover'd, as might lead us to the means whereby excessive cold kills men in northern countries. I expos'd a young rabbet all night to a very vehement frost, without finding any other damage, than one of his legs swell'd and grown stiff. But in a rabbet purposely strangled, and presently expos'd intire to a severe degree of cold, we found ice produc'd in such parts as wou'd have caus'd us to prosecute the experiments, had not the want of such animals hinder'd us.

It is affirm'd by some eminent modern writers, that water impregnated with the saline parts of a plant, and afterwards frozen, will exhibit

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We therefore lately try'd what cou'd be done with decoctions, that were richly imbued and highly ting'd with the ſpirituous parts of the vegetables; but the ice was by no means ſo figured as the tradition promiſes: and I remember, that having made a lixivium with ſixteen parts of water, and one of the ſalt of pot-aſhes, and expos'd it in a thin glaſs-vial to an exceeding cold air, we found much ice produc'd thereby, that lay on the top in little ſticks, not unlike thoſe priſmatical bodies into which ſalt-petre ſhoots; and the parts of this ice that were beneath the water ſhot into thin parallel plates, exceeding numerous, but nothing reſembling trees, by the incineration whereof *Polonian* pot-aſhes are made.

Bartholine, indeed, ſays, that the water wherein cabbage has been boiled, will, when frozen, repreſent a cabbage; the vegetable ſpirits being, as he ſuppoſes, concentrated by the cold. How well this experiment may ſucceed when made in a cold country I know not; but filtring a ſtrong decoction of cabbage thro' cap-paper, we froze it in a thin glaſs-vial by means of ſnow and ſalt; the ice did not either appear to have any thing in it like a cabbage, or remarkably different from other ice. And we afterwards expos'd a decoction of the ſame, to be congeal'd by the nocturnal air; but neither this way did the experiment ſucceed. And tho' once a few ounces of the decoction being lightly frozen in a vial, there appear'd in the thin ice that adher'd to the inſide of the glaſs, a figure not very unlike that of a cabbage-leaf; (and perhaps ſome ſuch accident may have invited our learned author to think, that the repreſentations of cabbages wou'd conſtantly appear in their frozen decoctions;) yet this configuration ſeem'd only caſual; for by freezing the decoctions of ſeveral herbs, ſome of them ſpirituous enough, as roſemary, penny-royal, *&c.* the ice I obtain'd from them, gave me no conviction of the truth of the tradition we are examining. On the contrary, I have, more than once, by freezing fair water after a certain manner, obtain'd ice, that ſeem'd much more to reſemble vegetables, than any decoctions of them that I ever try'd. And particularly, I ſometimes found, that by putting hot water into a ſlender glaſs cylinder, and agitating it in our frigorific mixture, ſo that it was very ſpeedily frozen thereby, it was congealed into an ice much more regularly and prettily figured than I have ſeen from the waters impregnated with the fixed ſalt of plants, or even of nettles; tho' that is ſo much boaſted of. In ſhort, a luxuriant fancy may produce apparitions in ice, which a more judicious obſerver cannot ſee. That a vaſt variety of figures are produced by congelation, no body denies; the ſame, alſo, happens in chymical preparations, and they will ſometimes appear regular; but 'tis plain, their generation is purely caſual.

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'Tis remarkable, that while the cold has ſtrange and tragical effects at *Moſcow*, and elſewhere, the *Ruſſians* and *Livonians* ſhould be exempt from them, who accuſtom themſelves to paſs immediately from a great degree of heat, to as great an one of cold, without receiving any viſible prejudice thereby. I remember, being told by a perſon of unqueſtionable credit, that it was a common practice among them, to go from a hot ſtove into cold water; the ſame was, alſo, affirmed to me, by another who reſided at *Moſcow*: this tradition is likewiſe abundantly confirmed by *Olearius*. "'Tis a ſurprizing thing," ſays he, "to ſee how far "the *Ruſſians* can endure heat; and how, when it makes them ready to "faint, they go out of their ſtoves, ſtark naked, both men and women, and "throw themſelves into cold water; and even in winter wallow in the ſnow."

I had ſeveral years ſince the curioſity to try, whether there were any truth in the tradition, that the rays of the moon are cold; but notwithſtanding all my care to make trials in clear weather, when the moon was about the full, and with the aſſiſtance of a thermometer, I could not perceive, by any concentration thereof even upon a black object, that her light produced any ſenſible degree either of heat or cold: but, perhaps, others with very large glaſſes may be more ſucceſsful. I cannot, however, help ſuſpecting, that the learned phyſician *Sanctorius*, miſtook in aſſerting the light of the moon to be conſiderably hot, when thrown thro' a burning-glaſs upon the ball of a common weather-glaſs; whereby, he ſays, the water was conſiderably depreſſed, as appeared to many of his diſciples, in a circle of whom the obſervation was made. For my glaſs was much better than his ſeems to have been; and my trials were, perhaps, as carefully and impartially made as his. But, probably, his ſcholars, whilſt they ſtood round his thermometer, and ſtooped to ſee, by ſo dim a light, the event of the experiment; the unheeded warmth of their breath and bodies might, unawares to *Sanctorius*, affect the air included in the weather-glaſs, and cauſe that depreſſion of the water, which he aſcribed to the moon's heat.

We took a ſealed weather-glaſs, about ten inches long, furniſhed with ſpirit of wine; and having cauſed a hole to be made in the cover of a box, juſt wide enough for the ſmaller end of the glaſs to be thruſt in at, we inverted the thermometer into it, ſo that the ball reſted upon the cover, and the point tended directly downward; then we placed about the ball, a little ice and ſalt, and thereupon obſerved the tinged ſpirit, in a very few minutes, to aſcend above an inch higher than its former ſtation; and it would, perhaps, have riſen farther, if the application of the frigorific mixture had been continued: by which, and another ſucceeding experiment, made to the ſame purpoſe, it ſeems the condenſation of liquors by cold, is not always effected by their proper gravity only, which may uſually ſuffice to make the parts fall cloſer together: but whether in our caſe, the contraction be aſſiſted by ſome little tenacity in the liquor, or by the ſpring of ſome little aerial or other ſpirituous

ſpirituous and elaſtic particles, from which the inſtrument was not perfectly freed when ſealed up, or which happened to be generated within it afterwards, remains to be enquired into.

There is a famous tradition in *Muſcovy*, and ſome other cold countries, that 'tis uſual, out of ponds and rivers, to take great numbers of benumb'd ſwallows, incloſed in pieces of ice; upon thawing whereof, in a warm room, the birds come to themſelves, and fly about amazedly for a while, but not long ſurvive ſo great and ſudden a change. This phenomenon I have been aſſured, by a perſon of honour, who was commanded by a great prince to inquire into the truth of it, was affirmed to him as certain by the moſt eminent and ſober perſons he could meet with. And an intelligent perſon of quality in *Poland* acquainted me, that in the parts where he liv'd, it was a very general and unqueſtion'd opinion, that ſuch birds often hid themſelves, all the winter, under water, in ponds, lakes, and ſedgy places, and that the fiſher-men draw them up in the manner already mentioned. But as for their being taken up in ice, he told me, he had not heard of it; tho' I ſee not why, in caſe they commit themſelves to ſhallow waters, as thoſe of ponds and ſedgy places often are, a ſharp laſting froſt may not, ſometimes, reach them. And, therefore, what left me the greateſt ſcruple about this tradition, was, that this curious gentleman could not affirm, he had ever ſeen any example of the thing he related.

It is a tradition handed down and received from *Ariſtotle*, that hot water will ſooner freeze than cold. But I could never find any truth in the aſſertion.

We took three porringers near of the ſame ſize, and filled one with cold water, another with water that had been boiled, but was now moderately cool, and a third with hot water, and expoſed the three together in the ſame place, to the freezing air, at half an hour after eight a clock, and found the porringer of cold water began to freeze at $\frac{1}{4}$ after ten. That which contained the water that had been heated and cooled again, began to freeze at $\frac{3}{4}$ paſt ten; and that which contained the hot water, at half an hour after eleven; ſo that all froze within the compaſs of two hours: yet the cold water began to freeze an hour and a quarter ſooner than the hot. Theſe were earthen porringers, but I alſo made the experiment in others of metal; and then, too, the cold water began to freeze, both before that which had been heated, and cooled again, and long before the hot. Another time I meaſured the water out by ſpoonfuls, into porringers, that the quantities of water might not be conſiderably unequal; and then, alſo, the cold water froze a conſiderable while before the hot. Upon repeating the experiment with greater caution, the cold water being put out with the reſt at $\frac{1}{4}$ after ſix, it began to freeze before $\frac{1}{4}$ an hour after ſeven. The water heated and cooled again began to freeze at $\frac{3}{4}$ after ſeven; and theſe having ſtood for a pretty while by me, I ſent for the hot water, and found it not to be in the leaſt

PHYSICS. leaſt frozen at half a quarter after eight. So that ſuppoſing it to continue half a quarter of an hour longer, before the beginning of its congelation, as it afterward did at the leaſt, it was twice as long, e'er it began to freeze, as the cold water had been. By which we ſee how well their labour was beſtowed who have puzzled themſelves and others to aſſign the reaſon of a phenomenon that might eaſily have been found upon trial to be chymerical.

I have been the more circumſtantial in theſe trials, that I might expreſs a civility to *Ariſtotle*; and becauſe artificial congelations are not ſo proper for this purpoſe. For having formerly taken two pipes of glaſs made on the ſame cylinder, that they might be of an equal bore, ſealed each of them at one end, filled them to the ſame height, and then ſtirred them together in a mixture of beaten ice, water, and ſalt, I found both parcels of water to freeze too ſuddenly, to ſhew a notable diſparity in the time they remain'd uncongealed. Having made the ſame experiment with ſlender glaſs pipes, and for greater caution, put the hot water firſt into one glaſs, then into the other, we once found that the hot water froze firſt; which wondering at, we examined the glaſſes, and perceiving one of them to be more conical where it had been ſealed than the other, it appeared that the water in this part, being ſuddenly frozen by reaſon of the ſlenderneſs of the glaſs, there accelerated the congelation of the reſt.

'Tis ſaid, indeed, by a commentator upon *Ariſtotle*, that his experiment will ſucceed, if by heated water we underſtand water that has been heated and ſuffered to cool again, 'till it be reduced to the temper of other cold water; for this refrigerated water, he ſays, he has found to congeal much ſooner than the other ſort. But this, I confeſs, I am very unapt to believe. For having often cauſed cold water to be expoſed to the air in froſty weather, together with ſome which had been heated and cooled again, the events did not anſwer this aſſertion; tho' due regard was had to the moſt conſiderable circumſtances in ſuch an experiment. But for farther ſatisfaction, we took two porringers of the ſame ſize and ſhape, one of which, we almoſt filled with common cold water, and the other with an equal quantity of ſuch as had been heated and cooled again; this done, I appointed one to examine the tempers of theſe waters with an exact weather-glaſs; and being both reduced to the ſame temper, they were expoſed to a very ſharp air, and watched by the ſame perſon, who finding them to begin to freeze, as it were at the very ſame inſtant, brought the two porringers to me, in each of which, I ſaw the bare beginning of congelation in the upper ſurface of the waters, where they were contiguous to the containing veſſels.

It is a current, and almoſt univerſal tradition, that when ponds or rivers are frozen over, unleſs the ice be ſeaſonably broke in ſeveral places, the fiſh contain'd therein will die for want of air; but whether this be well grounded, I dare not determine till farther trial has been made: for that fiſh cannot live without any more air than they find interſperſed

in

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in the water where they ſwim, has not, that I know of, been ſufficiently prov'd; and, poſſibly, there may be other reaſons aſſign'd of the death of the fiſh in ponds frozen by very ſharp froſts. For who knows what the locking up of ſome kinds of ſubterraneal ſteams, that freely aſcend thro' fluid water, may do towards vitiating and infecting it? Perhaps, alſo, the excrementious ſteams that inſenſibly iſſue out of the bodies of the fiſh, may, by being pent up, contribute, in ſome caſes, to render the water noxious. For being deſirous to learn, from a perſon curious in preſerving and tranſporting fiſh, whether ſome fiſh would not quickly languiſh, grow ſick and die, if the water they ſwam in, were not often ſhifted; he aſſured me, ſome kinds of them would: and it has not yet, that I have heard of, been tried, whether, tho' ponds ſeldom freeze to the bottom, yet the water that remains under the ice, may not, even whilſt it continues uncongealed, admit a degree of cold, that tho' not great enough to turn water into ice, may yet deſtroy fiſh within leſs time than the ſurface of a pond often continues frozen.

To try whether ice, by denying acceſs to the air, would deſtroy fiſh, I procured a glaſs veſſel with a large belly, and a long ſlender neck; and having filled it with water, and ſome live gudgeons, we paſs'd the neck of it thro' a hole that was made in the midſt of a metalline plate; which ſerved alſo to ſupport a mixture of ice and ſalt, applied round about the extant parts of the glaſs. By this contrivance, I propoſed to myſelf a double advantage; firſt, that as in broad veſſels, one cannot, eaſily, be certain that the ſurface of the water is quite frozen over in every part, I could thus ſatisfy my ſelf of that, by inverting the glaſs, and obſerving that the ice had ſo exactly choaked up the neck, that not a drop of water could get out, nor any bubble of air get in, and yet the fiſh have liberty to play in the ſubjacent waters. Secondly, the frigorific mixture, being here applied to the neck, none of the water was congealed, or extremely refrigerated, but that which lay in the neck; ſo that there ſeemed no cauſe to ſuſpect, that if the fiſh ſhould die in the water, it was rather cold than want of air that killed them. But having not proſecuted theſe trials, to the utmoſt, I ſhall lay no great ſtreſs upon them; yet I remember that the included fiſh, at this time, continued long enough alive, to make me ſtrongly ſuſpect the truth of the vulgar opinion.

I afterwards cauſed ſome of the ſame kind of fiſh to be put into a broad and flat earthen veſſel, with but little more water than ſufficed to cover them; and having expoſed them all night to a very intenſe degree of cold, I found them the next morning alive, and ſeeming not to have been much prejudiced, either by the cold, or excluſion of air. 'Tis true, there was a very large moveable bubble under the ice, that ſeemed to have been generated by the air, or ſome analogous ſubſtance, emitted out of the gills, or bodies of the fiſh; for the ſurface of the water was exactly frozen over. And that this bubble might poſſibly proceed

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PHYSICS. proceed from the fiſh themſelves; I the rather ſuſpect, becauſe, having, at different ſeaſons of the year, kept ſeveral ſorts of fiſh, for many days, in glaſs veſſels, I have often ſeen them raiſe their mouths above the ſurface of the water, and there ſeem to gape for air, and afterwards let go, under water, out of their mouths and gills, ſeveral bubbles, which ſeem'd to be portions of the air they had thus taken in. And particularly, in lampries, I have with pleaſure obſerved, that being taken out of the water into the air, and then held under water again, they very manifeſtly appeared forcibly to ſqueeze out of thoſe ſeveral little holes which are commonly miſtaken for their eyes, numerous bubbles of air. But to ſatisfy my ſelf further what degree of cold and want of air theſe gudgeons might ſupport, I expoſed two of them in a baſon of water, to an exceeding ſharp night, and the next day found the ice frozen in the veſſel, to a great thickneſs, and one of the fiſh frozen up in it, while there remain'd only a little of the water unfrozen, wherein the other fiſh ſwam: and the ice being afterwards partly thaw'd and partly broken, not only the latter was found very lively, but the other, which tho' when the ice was broke, it lay moveleſs, did, in a few minutes, ſo far recover, as to drag after it a large piece of ice, into which its tail remained inſerted. And tho' one of theſe, and ſome other gudgeons that had been already weakened, by long keeping, were once more expoſed to the froſt, in the baſon, and ſuffered to lye there till they were frozen up; yet the ice, in which they were incloſed, being broken, their bodies were grown ſtiff and crooked, and ſeemed to be quite dead, for they lay upon their backs in the water, yet one of them quickly recovered, and the other, not very long after, began to manifeſt ſigns of life; tho' he could not, in many hours, ſo far recover, as to ſwim upon his belly. 'Tis true, that theſe fiſh did not long ſurvive; but two or three probable reaſons might be aſſign'd for that; and particularly the ice they had been frozen up in had wounded them, as was manifeſt by ſome hurts that appeared upon their bodies. Some other gudgeons were irrecoverably frozen to death, by being kept incloſed in ice for three days. I likewiſe cauſed a couple of frogs; to be artificially frozen in a wide-mouth'd glaſs, furniſhed with a convenient quantity of water; but tho' they ſeemed, at firſt, to be incloſed in ice, yet looking nearer, I found that about each of them there remained a little turbid liquor unfrozen; as if it had been kept ſo by ſome expirations from their bodies. Wherefore cauſing them to be carefully frozen, and for a conſiderable time, I found, that notwithſtanding the ice, into which moſt part of the water was reduced, one of them, before the ice was perfectly broken, appeared to be alive; but the other lay moveleſs, ſtiff, and with the belly upwards, in a baſon of cold water, wherein it lay caſt; tho' in a very few minutes, he began to ſwim about therein. Upon the whole, tho' the tradition we have been examining, may, perhaps, have ſomething of truth in it; yet it ſeems to deſerve a farther inquiry, both in regard to the matter of fact, and to the cauſe of the effect.

That

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line, in his treatise of the use of snow, brings several passages out of authors to make it good; to which I shall add the testimony of Dr. *Fletcher*, who speaking of the fruitfulness of the soil in *Russia* says, "this fresh and "speedy growth in the spring, seems to proceed from the snow; which, "during the winter, being spread over all the country, keeps it warm "from the frost; and in the spring, throughly drenches and soakes the "ground, which is of a sandy nature."

I thought it might give some light into the nature of cold, to try whether two liquors, by being mixed together, and losing their fluidity, so far as to obtain the consistence of an unguent, would produce any sensible degrees of that quality. This I attempted by immersing, for a competent time, the ball of a tender sealed weather-glass, into each of the liquors apart; and then into the soft mixture, composed by their union. But tho' a strong solution of minium, or calcined lead in spirit of vinegar, or a very strong infusion of good quick-lime in water, will, either of them, coagulate a just proportion of good sallet oil into such a consistence; yet for want of a sealed thermometer, sufficiently tender, I cannot now repeat the experiment; therefore dare not draw any conclusion from it: tho' if I remember well, upon shewing one of these mixtures to an ingenious person, neither he nor I could perceive, that the liquors, by being deprived of their fluidity, had required any degree of coldness, discoverable by a sealed weather-glass.

XXV.

The vulgar notion of an antiperistasis examined.

It has long been supposed agreeable to the wisdom of nature, that cold and heat should both of them be endued with a self-invigorating power, which each might exert when surrounded by its contrary; and thereby prevent their mutual destruction. Thus 'tis supposed, that in summer, the cold expelled from the earth and water by the sun's scorching beams, retires to the middle region of the air, and there defends it self against the heat of the superior and inferior. And thus, also, in summer, when the air about us is sultry hot, we find, that cellars and vaults, have the opposite quality; so, in winter, when the external air freezes the lakes and rivers, the internal air, in the same vaults and cellars, becomes the sanctuary of heat: and water, fresh drawn out of the deeper wells and springs, in a cold season, not only feels warm, but manifestly smokes. And having purposely inquired of ingenious men, who had been very deep under ground, some in coal-pits, and some in mines, one of them affirmed, that at the bottom of a groove, he found it very hot in *September*; another, that he often, in such places, found it hot enough to be troublesome in winter; and a third, who is a master of mines, that he found them hot all the year long. And to manifest, that such ob-

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PHYSICS. ſervations will hold, even in cold regions, Captain *James*, giving an account of *Charlton* iſland, ſays "that his men found it more mortifying "cold to wade thro' the water in the beginning of *June*, when the ſea "was full of ice, than in *December*, when it was increaſing." He adds, "that from their well, out of which they had water in *December*, they "had none in *July*." And to ſtrengthen the obſervation yet further, an ingenious phyſician, who liv'd ſome years in, and about *Moſcow*, told me, he has there ſeen ſome ſprings, whoſe water froze not at all near the ſpring-head, but that, at a great diſtance from thence, it began to be thinly cas'd over with ice. He added, that his own well was about ſix fathom deep, from the ſurface of the earth, to that of the water; that the water in it was about three or four fathom deep; that this well froze not all the winter; nor the well of his neighbour, which was but one fathom deep to the ſuperficies of the water; and that when a bucket of water was newly drawn, it would, if agitated, ſmoke; but that from the well itſelf, when the water in it was left quiet and undiſturb'd, he did not perceive any ſmoke to riſe.

And having purpoſely inquired, whether, in the winter he found it as hot in cellars at *Moſcow*, as it uſually is in that ſeaſon in ours; he anſwered, that when the doors and windows were carefully ſhut, to hinder the immediate commerce betwixt the included and external air, he often found, if he ſtay'd long in his cellar, it would not only defend him from the ſharpneſs of the *Ruſſian* cold, in winter, but keep him almoſt in a ſweat, tho' he laid aſide his furs. So that if we may rely upon the teſtimony of our ſenſes, 'tis argued, we muſt neceſſarily admit cellars to be warmer in winter than in ſummer, and conſequently allow an *Antiperiſtaſis*.

But conſidering the reaſon of the thing abſtracted from the experiments that are pretended to prove an *Antiperiſtaſis*, it ſeems very rational to reject it. For in the firſt place, according to the courſe of nature, one contrary ought to deſtroy, not to ſtrengthen another. And next, 'tis a maxim, that natural cauſes always act as much as they can. And certainly, as to our caſe, wherein we treat not of living creatures, I cannot but think the axiom phyſically demonſtrative. For inanimate agents act not by choice, but by a neceſſary impulſe; and not being endow'd with underſtanding and will, they cannot, of themſelves, be able to moderate or ſuſpend their actions. Nor is there any danger, that cold and heat, whoſe cauſes are ſo rooted in nature, ſhould be loſt in the world, tho' each parcel of matter, that happens to be ſurrounded with bodies, wherein a contrary quality reigns, were not endowed with an incomprehenſible faculty of ſelf-invigoration. And nature either does not need the help of this imaginary power, or often has recourſe to it to very little purpoſe: ſince we ſee, that tho' theſe qualities ſubſiſt in the world, yet, in fact, bottles of water, wine, and other liquors, carried up and down in the ſummer, are regularly warmed by the ambient air. And in *Muſcovy*, and other cold

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cold northern countries, men, and other animals, have often their vital heat destroyed by the cold that surrounds them, being thereby actually frozen to death. And I wonder, that the followers of *Aristotle* should not take notice of that famous experiment, whereby he pretends, that hot water will sooner congeal than cold. For if the matter of fact were true, it would sufficiently manifest, that the heat harboured in the water, is destroyed, not invigorated by the coldness of the air that surrounds it. And tho' it is true, that white surrounded with black, or black with white, becomes thereby the more conspicuous; yet 'tis acknowledged, that there is no real increase, or intension of either quality, but only a comparative one in regard to our senses, obtained by this comparison. Nor does a pumice-stone grow more dry than it was in the fire or earth, by being transferred into the air or water; and consequently surrounded with either of those two fluids, which the schools teach to be moist elements: neither will a piece of dim glass become really more transparent, tho' one should set it in a frame of ebony. 'Tis commonly, indeed, alledged, as a proof of the power nature has given bodies of flying their contraries, that drops of water, falling upon a table, will collect into little globes, to avoid the contrary quality in the table, and keep themselves from being swallowed up by the dry wood: but the cause pretended, has no interest in the effect; for little drops of water, where the gravity is not great enough, to surmount the action of the surrounding fluid, if they meet with small dust upon a table, gather it up as they roll along, and their surfaces being covered with it, do not immediately touch the board, which else they would stick to. And to shew that the globular figure, which the drops of water, and other liquors, sometimes acquire, proceeds not from their resisting of dryness, but either from their being every way press'd, at least, almost equally by some ambient fluid, of a disagreeing nature, or from some other cause differing from that the schools would assign; the drops of water which swim in oil, so as to be surrounded with it, will be, likewise, globular; yet oil is a true moistening liquor as well as water. And the drops of quick-silver, tho' upon a table they are more disposed than water, to gather into a round figure, yet that they do it not as humid bodies is evident; because quick-silver broken into drops, will shew most of them globular, not only in oil, but in water. And that it is from the incongruity it has to certain bodies, that its drops refuse to stick to a table, but gather themselves into little spheres, as if they design'd to touch the wooden plain in a point, appears, because, tho' the same drops will retain the same figure on stone or iron, yet they readily adhere to gold, and lose their sphericity upon it; tho' gold be a much drier body than wood, which, as far as distillation manifests, must contain numerous humid parts of several kinds. But as to the *Antiperistasis* of cold and heat, the *Peripatetics* talk of those qualities being each surrounded by its opposite, as if both of them had an understanding,

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PHYSICS. and foreſight, that in caſe it did not gather up its ſpiris, and guard againſt its antagoniſt, it muſt infallibly periſh; which is to transform phyſical agents into moral ones. And as reaſon declares againſt the common opinion, ſo experiment alſo may be alledged againſt it.

The grand experiment, which a late champion for *Antiperiſtaſis*, makes his leading argument to eſtabliſh it, and which is ſo generally urged on that occaſion, ariſes from the heating of quick-lime in cold water. Now, I cannot but here admire at the lazineſs and credulity of mankind, who have ſo long, and generally acquieſced in what they might ſo eaſily have found to be falſe; for if, inſtead of cold water, you quench the lime with hot water, the ebullition will be, oftentimes, far greater than if the liquor were cold. And this might well be expected; hot water being much fitter than cold, ſuddenly to pervade the body of the lime, and haſtily diſſolve, and ſet at liberty the fiery and ſaline parts, wherewith it abounds. And what a greater intereſt ſalts may have in producing ſuch heats than cold, I have alſo tried by pouring acid ſpirits, and, particularly, ſpirit of ſalt upon good quick-lime. For by this means there would be a far greater degree of heat excited, than if I had uſed common water: and this, whether I employ'd the ſpirit cold or hot. For in either caſe, ſo ſmall a portion, as about the bigneſs of a wallnut of lime, put into a ſmall glaſs, would, by the gradual addition of a little ſpirit of ſalt, both hiſs, ſmoke, and boil very ſurprizingly; and notwithſtanding the ſmall quantity of the matter, conceive ſo great a heat, that I was not able to hold the glaſs in my hand. And to ſhew how little, heat excited in quick-lime by cold water, proceeds barely from the coldneſs of that liquor: I cauſed a parcel of good lime to be beaten ſmall, and putting one part of it into a glaſs veſſel, I drench'd it plentifully with oil of turpentine, more than it would imbibe; the other portion I likewiſe drench'd with common water; and both theſe liquors having ſtood in the ſame room, that they might be reduced to a like degree of coldneſs, the event was, that the oil of turpentine, notwithſtanding its actual coldneſs, and the great ſubtilty and penetrancy of parts, which it has in common with other chymical oils, being of an unfit texture, ſeem'd not to make any diſſolution of the powdered lime; and did not, for ſeveral hours, that I kept it, produce any ſenſible heat therein; whilſt that part on which common water had been poured, ſoon conceived ſo ſtrong a heat, that it broke a large open-mouth'd glaſs, into the bottom whereof it was put; and not only grew ſo hot, that I could not endure to hold it in my hand, but ſent out at the mouth of the glaſs, tho' that were conſiderably diſtant from the lime, a large white fume, ſo hot, that I could not bear to hold my hand over it. And to prevent an objection, which I foreſaw might be raiſed againſt the experiment made with oil of turpentine, from the oleaginous nature of that liquor? I covered a piece of the ſame ſort of quick-lime, with highly rectified ſpirit of wine; but tho' I left them together all night,

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night, yet I perceived not, that the liquor had at all ſlaked the lime, which continued in an intire lump, till ſubſtituting common water, it quickly appeared to be ſlaked, and fell aſunder into a kind of minute white powder. PHYSICS.

In freezing a baſon to a joynt-ſtool, with a mixture of ſnow and ſalt, by the fire-ſide, 'tis pretended, that the fire ſo intends the cold, as to enable it to congeal the water, that ſtagnated upon the ſurface of the ſtool, betwixt that and the bottom of the veſſel. But how little need there is of *Antiperiſtaſis* in this experiment, appears from hence, that I have purpoſely made it with good ſucceſs, in a place where there neither was, nor ever probably had been, a fire: and this trial I could confirm by ſeveral other experiments of the like nature; but this one is ſufficient.

'Tis farther delivered for fact, that if, having almoſt filled a large pot with ſnow, and placed in the middle of the ſnow a vial full of water, this pot be put over the fire, the coldneſs of the ſnow will be ſo increaſed by the heat, from which it flies into the water, as to turn that liquor into ice. But tho' I ſeveral times tried the experiment, yet neither in earthen, nor in ſilver veſſels, could I ever produce the promiſed ice. And I remember, that a very learned man, who wondered to find me ſo diffident of what he ſaid he knew to be true, readily undertook to convince me by ocular proof; but with no better ſucceſs than I had before.

And in caſe the trial ſhould ſucceed, ſome time or other, yet will there be no neceſſity of deriving the effect from *Antiperiſtaſis*. For tho' the fire would then contribute to the effect, by haſtening the diſſolution of the ſnow, yet the heat of the fire does but remotely, and by accident, cauſe the production of ice; ſince other agents will do the ſame thing, that are qualified to make a quick diſſolution of the ſnow, whether they be hot or not; as ſpirit and crude ſalt of nitre, will, either of them, by a due application, bring ſnow, by diſſolving it, to congeal water; tho' the ſpirit and the nitre be generally agreed upon to be actually cold, and one, if not both of them, to be potentially cold too.

Having thus diſpatch'd the experiments pretended to prove an *Antiperiſtaſis*, I ſhall next examine the obſervations, alledged to that purpoſe; of which the principal are, the coldneſs of the middle region of the air; the increaſe of men's appetite in winter; the generation of hail; and the heat and cold in cellars, and other ſubterraneal places, when the contrary quality reigns in the air.

To begin with the firſt of theſe. I will not now diſpute, whether the ſecond region of the air, have really the coldneſs aſcribed to it: I ſee no neceſſity, however, of employing an *Antiperiſtaſis*, to keep the ſecond region of the air for the moſt part cool. Without taking in the cauſe imagin'd by the ſchools, an obvious and ſufficient one may be eaſily aſſign'd hereof. For the air being, as to ſenſe, cold of its own nature, ſo that

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by its reflected rays; their heat is so languid, by that time they arrive, dispers'd, at the second region of the air, as to be unable to over-power its natural coldness, increased perhaps by some frigorific spirits, that may find a more commodious harbour there, than in other parts of the atmosphere. And whatever be the true cause of the coldness in the middle region of the air, I admire to find it so confidently ascrib'd to *Antiperistasis*, by the *Aristotelians*: for, according to them, 'tis the nature of the air to be as well hot as moist; and according to the same, both the upper region of the air always, and the lower in summer, is kept hot, the former by the neighbourhood of the imaginary element of fire, and the latter by the reflection of the sun-beams from the earth: how therefore comes *Antiperistasis* to take place here? For, as they say, those bodies have their cold and heat increas'd by *Antiperistasis*, that are on both sides assail'd by others of a contrary quality, to that which is natural to the surrounded body; but the whole element of air, and consequently the middle region, being, as they would perswade us, hot of its own nature; what shadow of probability is there, that the highest and lowest regions, by being hot, should make the middle region, which is also naturally hot, intensely and durably cold? However, it does not appear, if the air be naturally rather cold, than hot, that the second region must owe the intenseness of that quality to an *Antiperistasis*. For the ground of this opinion, being, that both the first and the third regions are considerably hot, I would gladly find it prov'd as to the upper region. 'Tis true, there are two reasons alledged, to shew the heat of the higher region of the air, but neither of them seems cogent. The first is, its vicinity to the element of fire. But if we consider the distance of that element, which they place contiguous to the orb of the moon; and how little nearer to it the concave part of the upper region is, than the convex of the middle, we may easily conceive, that in two distances, that are both of them so immense, so small a disparity cannot be more considerable, than the greater nearness of one side of a sheet of paper held at three yards distance from an ordinary fire, in comparison of the other side of the same paper; or than the distances of a small wart, and of the neighbouring parts of the face, when a man comes within two or three yards of the fire. But 'tis not worth while to prosecute this consideration, because the argument against which 'tis alledg'd, is built upon the groundless supposition of the element of fire; a figment which many of themselves are asham'd of; and indeed its existence is as little to be discovered by reason, as perceiv'd by sense.

The other argument for the heat of the third region of the air, is, that fiery meteors are kindled by it. But not here to examine, whether all meteors that shine, and therefore pass for fiery, are really kindled

kindled exhalations; we ſee, that in the lower region of the air, and in winter, thoſe fires called either *Helena*, or *Caſtor* and *Pollux*, are generated in great ſtorms, and hang about the ſails and ſhrouds of ſhips. Nay, do not we much more frequently ſee, that lightning is produced at all ſeaſons of the year; for in warmer countries thouſands have obſerved it to thunder (and ſo have I in winter) in the middle region of the air? And if 'tis not the heat of the lower part of the air, that kindles thoſe exhalations; and if, notwithſtanding the coldneſs of the ſecond region, fiery meteors may be frequently generated there; I ſee not how the production of ſuch meteors argues the heat of the third region of the air. And if that region be not hot, then it will be eaſily granted, that the coldneſs of the ſecond muſt very improperly be attributed to ſuch an *Antiperiſtaſis*, as it is generally aſcribed to. PHYSICS.

Let us next conſider that aphoriſtical ſaying of *Hippocrates*, "the *Viſ-* "*cera* are hotteſt in the winter," together with the obſervation whereon it ſeems to have been grounded. I will not now enquire whether any arguments for the contrary may be drawn from the heat and thirſt men feel in ſummer, and the refreſhment they then find by drinks, fruits, and other aliment actually cold; what I principally intend is, that I much more doubt the matter of fact, than that, in caſe it be true, it may be accounted for without the help of *Antiperiſtaſis*, in the vulgar notion of that term.

And firſt, the proof uſually brought of the greater heat of men's ſtomachs in winter, is, that they then have a greater appetite. But the aphoriſm ſuppoſes digeſtion to be made in the ſtomach by heat; and conſequently that the ſtronger digeſtion made in the winter, is an argument the ſtomach is then hotter than in other ſeaſons of the year. The error of this ſuppoſition, need not be ſolemnly proved, ſince there are ſeveral things in nature, that agree not with it, and particularly the ſtrong concoction made in ravenous fiſh, whoſe ſtomachs and blood are, as I have purpoſely obſerved, ſenſibly cold. But if it ſhould in ſome caſes prove true, that there is really in men's bodies a far greater heat in winter than in ſummer, yet this would not infer an *Antiperiſtaſis* in the ſenſe, wherein I oppoſe it. For the vital heat lodg'd in the heart, always generating out of the blood and juices, that continually circulate thro' that part, plenty of ſpirits and warm exhalations, which tranſpire thro' the pores of the ſkin in much greater quantities, than, notwithſtanding the affirmations of *Sanctorius*, any thing but my own trials could have perſuaded me; theſe warm ſteams finding the pores of the ſkin ſtraitned and ſhut up, gradually grow more numerous in the body, and thereby heat the ſtomach, as well as the other internal parts. Perhaps, alſo, the ſame cooling corpuſcles or temperature of the air, that produce cold in winter, may, by ſhutting in certain kinds of effluvia, or altering the motion or texture of the blood, reduce it to ſuch a diſpoſition, as ſhall increaſe the appetite,

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PHYSICS. as well as the concoction in the ſtomach, promoted by the ſtomachical menſtruum, or ferment, which either is newly generated in winter, or more plentifully ſupplied (by the circulation of the blood) in that ſeaſon than in others. And to ſhew, that a keen appetite may be procur'd by agents endow'd with very diſtinct and contrary qualities; aromatic ſauces, wine and vinegar, all of them, in moſt men, beget an appetite, tho' the two former be confeſſedly hot, and the latter cold. And ſo wormwood, and the juice of lemmons, have both of them frequently reliev'd dull and weak ſtomachs; tho' the one be confeſſedly a hot ſimple, and the other a cold one. And in ſome caſes, either the frigorific corpuſcles themſelves, and perhaps ſome other unknown to us, brought along with them, may ſo ſollicit the ſtomach, as to cauſe an eager appetite, not preciſely by their being cold or hot, but by their peculiar nature; as we have inſtances of ſome among us, who by walking in the ſnow, procure an inſatiable hunger. And the learned *Fromundus* relating how himſelf, by walking long on the ſnow, was ſurpriz'd with ſuch a canine appetite, takes notice, that the chief cauſe of the fainting was in the ſtomach: and that he found by his own experience, that part diſcompos'd, twitch'd and provok'd to retchings. He adds, that he thinks the chief cauſe of the *Bulimia* to conſiſt in certain ſteams, that peculiarly affect the ſtomach, which they gnaw and diſtend. And juſt before he obſerved, that ſtraining to fetch deep coughs is a preſent remedy in this diſtemper, by diſcharging the ſtomach and lungs of thoſe ſnowy ſpirits, which were either attracted in reſpiration, or had, ſome other way, inſinuated themſelves in thoſe parts: ſo that beſides the cold, abſtractedly conſider'd, the ſtomach may be peculiarly affected by other attendants of the frigorific corpuſcles, that grow powerful in froſty weather. To this it well agrees, that ſeveral have been ſubject to a *Bulimia* in our climate, who endure nothing near ſo great a cold, nor are ſo much diſorder'd by it, as multitudes of others, who in *Nova Zembla*, and other frozen regions, never complain'd of having contracted, even in the midſt of winter, any ſuch diſeaſe.

Another argument, urg'd in favour of *Antiperiſtaſis*, is borrowed from the production of hail, which is preſum'd to be generated in ſummer only, not in winter; and, according to the ſchools, is made in the loweſt region of the air, by the cold of the falling drops of rain being ſo highly intended by the warmth it meets with in the air near the earth, as to congeal the water wherein 'tis harbour'd. But tho' I think the generation of hail hard to be well explain'd; yet I reject the receiv'd doctrine about it, for ſeveral reaſons.

And firſt, 'tis not univerſally true, that hail falls not but in ſummer, or very hot weather; for I have myſelf obſerv'd it to hail at the latter end of *November*; and that when ſome froſty days had preceded, and when the coldneſs of the weather was complain'd of. Nay, the longeſt ſhower of hail that I remember to have ſeen, fell

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fell about a week before the end of *January*, on a night preceded by a very froſty day, which itſelf was preceded by the ſharp fit of froſty weather. And when the tedious ſhower was over, there came to the houſe, where I then was, a ſervant to one of my domeſtics, and related to her maſter, and others, that ſhe was miſled out of the beaten way, where the ſtorm found her, by an *Ignis fatuus* which ſhe long miſtook for a common light. Now, how the nocturnal air could kindle a fiery meteor by its coldneſs, and at the ſame time congeal the falling drops of water into ice by its warmth, I ſhall leave the patrons of *Antiperiſtaſis* to conſider; and only add, that doubtleſs other obſervations of the like kind have been often made, tho' perhaps ſeldom recorded: for within a very few weeks of this ſtorm, ſome ſervants of mine affirm'd they had obſerved it to hail two or three times beſides. PHYSICS.

Next, if *Ariſtotle* hath rightly aſſign'd the cauſe of hail, 'tis ſomewhat ſtrange it ſhould not fall far more frequently in ſummer, and eſpecially in hot climates, than it does; conſidering how often, in all probability, the drops of rain fall cold out of the ſecond region into the warm air of the firſt. And more ſtrange it is, that even in thoſe parts of *Ægypt*, where it rains frequently enough and plentifully, tho' not about *Grand Cairo*, yet about *Alexandria* and *Peluſium*, it ſhould never hail no more than ſnow, as the learned *Proſper Alpinus* affirms. Beſides, as to the generation of ſnow in the upper region of the air, and hail always in the lower, my own obſervation has afforded me many inſtances that ſeem to contradict the tradition. For I have obſerved that in many great grains of hail, beſides a hard tranſparent icy ſhell, there was, as 'twere, a ſnowy pith of a ſoft white ſubſtance; and this ſnowy part was moſt commonly in the middle of the icy, but ſometimes otherwiſe. And laſtly, the favourers of *Antiperiſtaſis* would have the drops of rain in their deſcent, to be congeal'd apart in the ambient air; but the irregular and angular figures we often meet with in hail, gives little countenance to this doctrine: and hail often falls in grains too large by far to comply with *Ariſtotle*'s conceit. For, not to mention the grains of hail I have myſelf obſerved to be of a bigneſs unſuitable to this opinion, ſeveral eye-witneſſes have inform'd me of their having obſerved much greater than thoſe I have done: and particularly an eminent virtuoſo of unqueſtionable credit, affirm'd to me, that he had at *Lyons* in *France* obſerv'd a ſhower of hail, many of whoſe grains were as large as ordinary tennis-balls, and which greatly damaged the window and tiles of the houſes, anſwerable to that unuſual bulk. And *Bartholine* declares, that he himſelf obſerv'd, in another ſhower of hail, grains of a larger ſize; a ſingle one weighing no leſs than a whole pound. But tho' this itſelf is little in compariſon of what I remember to have met with in authors; yet it abundantly ſuffices to diſprove the vulgar conceit about the generation of hail, till we meet in theſe countries with ſhowers of

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PHYSICS. rain, whoſe ſingle drops prove to be as large; which I preſume thoſe who aſcribe hail to *Antiperiſtaſis*, will not eaſily ſhew us.

I come now to conſider the laſt, and indeed the principal example, that is given of *Antiperiſtaſis*, the coldneſs of cellars, and other ſubterraneal vaults in ſummer, and their heat in winter.

And firſt, as to the refreſhing coldneſs which ſubterraneal places afford in ſummer, I both deny that they are then colder than in winter; and aſſert, that tho' they were, that coldneſs would not neceſſarily infer an *Antiperiſtaſis*.

We muſt conſider then, that in ſummer our bodies having, for many days, or weeks, been conſtantly ſurrounded with an air, which, at that ſeaſon of the year, is much hotter than in winter, or other ſeaſons? our ſenſes may eaſily impoſe upon us, and we be much miſtaken, by concluding upon their teſtimony, that the ſubterraneal air we then find ſo cool, is really colder than it was in the winter, or the ſpring; as they who come out of hot baths think the air of the adjoining rooms very freſh and cool, which they found to be very warm, when coming out of the open air, they went thro' thoſe warm rooms to the bath. And the depth and retiredneſs of theſe ſubterraneal caves keep the air they harbour, from being any thing near ſo much affected with the changes of the ſeaſon, as the outward air, that is freely expos'd to the ſun's rays, which pierce, with any ſenſible force, ſo little into the ground, that diggers ſeldom obſerve the earth to be dried and diſcolour'd by them beyond the depth of a very few feet. And I have found, in very ſhallow mines, not above ſix or ſeven yards deep, tho' the mouth were wide, and the deſcent perpendicular, the air was cool in the heat of ſummer; ſo that the free air, and our bodies that are always immers'd in it, being much warmer in ſummer than at other times; and the ſubterraneal air, by reaſon of its remoteneſs from thoſe cauſes of alteration, continuing ſtill the ſame, or but very little chang'd; it's no wonder there ſhould appear a difference, as to ſenſe, when our bodies paſs from one to another of them.

And ſuppoſing the air of cellars and vaults were really colder in ſummer than in winter, that is, were diſcovered to have a greater coldneſs not only as to our ſenſe of feeling, but as to weather-glaſſes; yet need not we have recourſe, for the ſolution of the difficulty, to an *Antiperiſtaſis*, which 'tis much harder to underſtand, than to find out the cauſe of the phenomenon; which ſeems, in ſhort, to be this; that as there are warm exhalations, in all ſeaſons, plentifully ſent up by the ſubterraneal heat, from the lower to the ſuperficial parts of the earth; theſe ſteams, (which in winter are in a great meaſure repreſſed, or checked in their aſcent, by the cold froſt or ſnow, that binds the ſurface of the earth, and choaks up its pores) which being detained in the ground, would temper the native coldneſs of the earth and water, and conſequently that of ſprings, and of the ſubterraneal air, are by the heat that

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chinks, which that heat opens on the ſurface of the ground, by which means the water of deep ſprings and wells, and the ſubterraneal air, being deprived of that which is requiſite to allay their wonted coldneſs, are left to diſcloſe a higher degree of it, and ſeem to have that quality increaſed, when indeed it is but freed from the mixture of its contrary that weakened it.

As for the heat we find in cellars and vaults in winter, the ſolutions already given will be applicable to that phenomenon alſo; which by this way is yet more eaſy to be accounted for than the other.

But it may be juſtly queſtioned, whether cellars, in general, are hotter in the winter than they are in ſummer. As for the teſtimony of our ſenſes, upon which alone men uſually conclude the affirmative, it may in this caſe eaſily deceive us. For thoſe places being ſheltred from the winds, and kept from a free communication with the outward air, they will be much leſs expoſed than others to the action of the agents, whatever they are, that produce cold in the air: ſo that our bodies being conſtantly immers'd in the air cooled by the winter, and conſequently brought nearer to the temper of that air; when thoſe bodies come into cellars, the ſubterraneal air muſt ſeem warm to us, tho' in itſelf it were unvaried as to its temper.

Now that many cellars are indeed colder in the midſt of winter, than in the heat of ſummer, tho' not in reſpect of our ſenſes, yet in reſpect of other bodies, which have not the ſame prediſpoſitions, I am induc'd to believe by ſome experiments I purpoſely made. Having on a froſty evening hung out in a garden two ſeal'd weather-glaſſes, that they might be reduced as near as poſible to the temper of the ambient air, I brought one of them into a cellar, and it ſoon began manifeſtly to riſe, and in two or three hours aſcended five or ſix diviſions, whilſt the liquor in the other ſealed weather-glaſs, that continued ſuſpended in the ſame part of the garden, rather a little ſubſided, than roſe; which ſhews that the air, harbour'd in cellars, is not ſo powerfully affected by the ordinary efficients of cold, as the free external air. And to ſhew that the ſubterraneal air, tho' it be leſs affected by the outward cold, may be ſomewhat affected by it, inſtead of growing hotter by *Antiperiſtaſis*; I ſhall add, that early in the morning, in froſty weather, the liquor in the ſame weather-glaſs appeared more ſubſided, than over night: which ſhews that the external air leſſened, not increaſed, the warmth of the air in the cellar. And having there placed a wide-mouth'd glaſs of oil, which in thawing weather remained all night fluid as before; the ſame liquor, the very next night, which proved ſeverely froſty, was ſo far frozen and congealed, as to ſink in other oil, and keep its ſurface exactly, tho' the glaſs were turned upſide down. And proſecuting my trial, I found, that in a ſharp froſt, and great ſnow, the liquor which over-night was beneath the fourth diviſion, a ſuddain thaw coming with a ſouth-wind, the next morn-

PHYSICS. ing in the ſame cellar the liquor was aſcended to the eighth. And long continuing the weather-glaſs in the ſame cellar, to watch its alterations every night and morning, I regiſtred more obſervations, that confirmed me in my opinion. And after theſe experiments, meeting with a learned *Polander*, I, without declaring my opinion, enquired of him, whether in his country he had at any time obſerved beer to freeze in cellars in froſty weather; who anſwered, that in the coldeſt winters, if the beer were ſmall, the barrels would often be frozen, but not if it were ſtrong. And I have myſelf obſerved here in *England*, barrels of beer to be frozen in the cellar in exceeding cold weather; ſo that one of them being full, and the liquor expanded by freezing, it was forced out at certain chinks, which ſeem'd to have been made by that expanſive force; and the liquor ſo thrown out, adhered in a conſiderable lump to the outſide of the veſſel; yet this cellar had its windows carefully ſhut, and lay not only near a kitchin, where fire was conſtantly kept, but had this principal mark of a good cellar, that in the heat of ſummer it afforded drink ſufficiently cool. And enquiring of the phyſician to the *Ruſſian* emperor, whether their cellars, at *Moſcow* were really very cold in ſummer, he anſwered they were not; that they had diſtinct cellars for ſummer and for winter; that their ſmall beer would quickly grow ſour in their cellars in ſummer, if their veſſels were not kept in ſnow; and therefore that their way was to make at the bottom of their ſummer cellars a deep layer of ſnow, on which they afterwards caſt a convenient quantity of water, whence the whole maſs might be turned into a kind of ice. In this ſnow they keep their caſks; making ſometimes a layer of ſnow, and a layer of caſks; and digging out their veſſels, as they have occaſion to uſe them. From all which it appears how groundleſly 'tis affirmed of cellars, that as they ſeem to the ſenſe, ſo they really are hotter in winter than in ſummer.

But if it ſhould happen, (as poſſibly it ſometimes may) that a vault or cellar is really warmer in ſummer than in winter; yet I ſee not why this ſhou'd drive us to acknowledge an *Antiperiſtaſis*: for neither could the effect be made out by that; nor would there be any neceſſity to have recourſe to it.

For ſuppoſing an *Antiperiſtaſis* intelligible, it were improper to alledge it in our caſe; ſince to invigorate the warmth of the air by the cold, the air muſt, according to the peripatetics, be environed with other cold bodies, and the heat retire as far as it can from them; and accordingly 'tis obſerved, that in winter the deepeſt cellars are warmeſt. But in the caſe before us, the ſubterraneal air, tho' above, it have the cold that reigns in winter; yet beneath, the ſubterraneal heat makes the earth very warm. The learned *Morinus* informs us, that about the year 1615. he viſited the mines of *Hungary*, and particularly deſcended into the deep gold mine at *Cremnitz*: and that after he had deſcended fourſcore or a hundred fathom, he found it exceſſively hot, tho' he had but a

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but alſo thoſe of ſeveral others, unanimouſly aſſured him, the lower region of the earth was all the year long very hot, as well in winter as he found it in ſummer: ſo that it ſeems in winter the heat of the ſubterraneal parts, leſs remote from the ſuperficies, cannot be increaſed by the coldneſs of the more internal parts of the earth, thoſe parts being themſelves conſtantly hot.

Indeed he ſays, that he found the ſupreme region of the earth, as he calls it, which is that next the air, exceedingly cold, both as he went down into the mine, and as he came up again; and this he aſcribes to *Antiperiſtaſis*. But he alſo relates, that 'twas in *July*, and in very hot weather, that he went down into the mine, and that he exchanged his clothes for a light looſe linnen garment, ſuch as the diggers wore; and this himſelf mentions, as that which much increaſed the coldneſs he felt: ſo that if beſides this we conſider, that he deſcended into a cooler place, his body being already effected with the great heat, which as he elſewhere takes notice, the ſeaſon had given the outward air; and being perhaps much heated by riding or walking to the mine; no wonder he found the change very ſenſible as he went down. And 'tis the leſs ſurprizing, that he found the upper region of the earth, as he calls it, more cold when he came up again: ſince beſides the toil of going down, and aſcending thro' narrow, low, and difficult paſſages, he came out of a place ſo exceſſively hot, that he tells us, the overſeer of the mine would not go back with him the ſame way he came, but took a far ſhorter, tho' a more dangerous way, cauſing himſelf to be drawn up in a perpendicular groove; becauſe he ſaid, 'twas very unhealthy, coming out of a place where the diggers work naked, and where they even melt in ſweat, to make any long ſtay in the upper region of the earth. So that this author, altho' he maintains *Antiperiſtaſis*, yet allows the upper region to be hot in winter, as well as cold in ſummer; and conſequently that in winter, it has not a cold region beneath, as well as above it. But beſides this, the matter of fact ſeems very favourable to my opinion; for I may juſtly refer the cold he felt near the ſurface of the earth to the deception of his ſenſe; but the heat he felt within the bowels of the earth, cannot be referred to the ſame cauſe: ſince he tells us, that at the top of the great and perpendicular groove, by which the mine-maſter was drawn up, there aſcended a large ſmoak, that, even above the mouth of it, felt actually hot. And beſides his own confeſſion, that the deep parts of the mine were more than ſeemingly hot, I can draw further proofs from theſe two circumſtances, that I have elſe-where met with in his narrative: the one, that on the ſurface of the earth, it was than exceſſively hot; another, that the ſmoak, which, notwithſtanding this heat appeared hot, had in its aſcent paſſed thro' four or five hundred feet

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PHYSICS. of a cold region of the earth, whereby it may well be ſuppoſed to have been much infrigidated. To theſe relations of *Morinus*, we may add, the arch-biſhop of *Upſal* affirms, that going in the year 1528 to viſit thoſe deep mountains (as he terms them) in *Poland*, whence they dig ſolid ſalt; and having deſcended fifty ladders, he found in the deeper places, that the workmen were naked, becauſe of the heat; ſo that ſuppoſing the time of the year not to be conſiderable in this caſe, it ſeems from hence, that, provided a man deſcends low enough into the bowels of the earth, he will find it very hot, even in places that want thoſe metals, or marcaſites, or other like mineral ſubſtances, by the action of ſaline liquors, or exhalations upon which, 'tis probable, the heat obſerved in mines may be produced.

I have hitherto ſhewn, that the heat of cellars and vaults in winter, has been very improperly aſcrib'd to *Antiperiſtaſis*. It has alſo been unneceſſarily aſcribed thereto. For as the air of thoſe places is protected from the greateſt part of the adventitious coldneſs that reigns in the outward air; ſo the ſubterraneal air has a poſitive cauſe of heat in winter, that it has not in ſummer. For as we formerly obſerv'd, in ſummer the pores of the earth being dilated by heat, the warm exhalations, that uſed to mix with moiſt vapours in the bowels of the earth, are call'd out, and exhal'd; but in winter, the ſurface of the earth, being hardened by froſt, or its pores clog'd, the hot ſteams, that, as we lately ſaw, continually, and in plenty aſcend from the warm region, or lower parts of the earth, are in great part detained and impriſoned in cellars, and other ſubterraneal cavities, where conſequently they produce ſuch a heat as to thoſe who come out of the cold air, may be very ſenſible. And this the rather, becauſe whilſt men, by the coldneſs of the ſeaſon, are more than ordinary careful to ſtop up the paſſages, at which the external air may get in, they at the ſame time ſtop up the vents, at which the ſubterraneous exhalations might get out. And a very grave author having occaſion to mention cellars, relates it, as a practice in ſeveral houſes of a town where he had been, to keep vents in their deep cellars, which, in the ſummer, were opened from time to time, to keep the places ſweet and wholeſom, and alſo to let out the warm exhalations, that would otherwiſe flat and deaden their liquors. And theſe ſteams were affirm'd to have been ſeveral times obſerved to aſcend viſibly into the free air, like ſmoak: which, ſeveral phenomena, and particularly what is ſaid of the hot fumes, that manifeſtly aſcended out of the great groove in the *Hungarian* mine, may render credible.

We come now to conſider that phenomenon, which is much urg'd in favour of *Antiperiſtaſis*, the ſmoaking of water, drawn in froſty weather, out of deep wells and ſprings.

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But ſurely 'tis very improperly that ſome urge for *Antiperiſtaſis*, ſuch examples as the ſtrange ſpring near the temple of *Jupiter Ammon*, which *Lucretius* and others obſerved to have been exceeding cold in the day time, and as hot at night; for, not now to examine, whether the ſtory be fabulous, or might not be aſcribed to ſome crafty trick of the prieſts, who deſign'd to impoſe upon *Alexander*, as well as others, and procure an admiration of the place; in this, and other the like caſes, for inſtance, the ſprings in the iſlands of *Maldivia*, mention'd by *Pyrad*, muſt be referred to the peculiar nature of the ſpring, or ſome other hidden cauſe; ſince if the water of them were but ordinary, and the phenomena the effects of *Antiperiſtaſis*, it might juſtly be expected, that the like ſhould happen in all ſprings; which is contrary to common experience. PHYSICS.

'Tis related, that in, or near the little *Daniſh* iſland *Hueena*, where the famous *Tycho* built his *Urani-Burgum*, there is a ſpring among many ordinary ones, that, even in the coldeſt winter, is never frozen; which, in theſe regions, happens exceeding rarely. *Olaus Magnus* alſo relates, that in another part of the king of *Denmark*'s dominions, *viz. Nidroſia*, one of the chief cities of *Norway*, there is a lake that never freezes. And the learned *Joſephus Acoſta* tells us, that, among a very great number of hot ſprings to be met with in *Peru*, "there is a courſe of water, "at the baths, which they call the baths of *Ingua*, which comes out "all hot and boiling, and that joining to it, there is another, whoſe "water is as cold as ice." He adds "that the *Peruvian* emperor, was "accuſtomed to temper the one with the other; and that it is wonderful to ſee ſprings of ſuch contrary qualities, ſo near one to another." Hence it ſhould ſeem, that ſprings may obtain very peculiar and ſtrange qualities from the nature of the places through which they paſs, or from other cauſes. And who knows what intereſt ſuch cauſes as we are ſtrangers to, may have in ſome phenomena, that are wholly aſcrib'd to the heat and cold of the ſuperficial part of the ground; and what effect they have upon many other ſprings ſome of which that are very deep, riſe, perhaps, from the warm region of the earth, and are there affected by the place; as both theſe and others may be by unknown mineral juices and ſteams; tho' we well know, that ſome of them, which are ſaline, without being at all ſenſibly hot, will powerfully reſiſt congelation?

But the ſmoaking of waters drawn from deep places in froſty weather, does not neceſſarily infer ſuch water to be warmer in winter; ſince that effect may proceed not from the greater warmth of the water, in ſuch weather, but from the greater coldneſs of the air. For a man's breath in ſummer, or in mild winter weather, becomes very viſible; the cold ambient air ſuddenly condenſing the fuliginous ſteams, diſcharged by the lungs; tho' in warmer weather, they are readily diffuſed in imperceptible particules through the air. And I have obſerved upon the opening of iſſues in ſome mens arms, that tho' no ſmoak be viſible in ſummer, it will be very conſpicuous in exceeding ſharp weather,

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PHYSICS. weather, tho' the arms ſeem to have leſs heat in froſty weather, than in ſummer; ſince in the former ſeaſon, they are manifeſtly more ſlender, the fleſhy parts and juices being condenſed by the coldneſs of the air. And tho' the inſenſible tranſpirations, continually made from all the parts of our bodies, are not viſible here, even in winter; yet in extremely cold countries, as *Nova Zembla*, or *Charleton* iſland, thoſe effluvia have been obſerved, not only to be thickned, but to be turned into ice it ſelf, ſometimes within-ſide the ſailors ſhoes. And here in *England*, having lately employ'd a labourer to dig a deep pit in very froſty weather, two ſervants of mine, who ſtood by to ſee him work, aſſured me, when they returned, that the ſteams of his heated body were frozen upon the out-ſide of his waiſtcoat.

And ſeeing how faſt the water in ponds and ditches, waſtes in ſummer, there is no cauſe to doubt, that it then continually exhales away more plentifully, than in winter; nay, in the ſummer, we often ſee, in the mornings or evenings, the face of the water cover'd with a miſt or ſmoak, that riſes out of it. And I have ſometimes obſerved this aggregate of exhalations to hover over the water, and make, as it were, another river of a lighter liquor, that conform'd it ſelf, for a conſiderable way, to the breadth and winding of the ſtream whence it proceeded. And I think it will be eaſily granted, that the water in ſummer time is, at leaſt, as warm at noon, when ſuch exhalations are not viſible, as in the morning when they are, tho' the air be colder at this part of the day, than at that; which obſervation gives us the true reaſon of the phenomenon.

And tho' notwithſtanding all this, it were made to appear, that, in ſome caſes, the ſmoaking water of ſprings, may be really warmer in winter than in ſummer; yet a ſufficient reaſon of the phenomenon appears from what I have already delivered above the detention of the warm ſubterraneal vapours by the froſt, ſnow, and rain, that render the earth leſs perſpirable in winter.

That there ariſe large warm ſteams, from the lower parts of the earth may be proved, not only by what is already mentioned of the *Hungarian* mines, but by the common complaint of diggers in moſt deep ones, who ſay they are often troubled, and ſometimes endangered by ſudden damps, which frequently ſo ſtuff up and thicken the ſubterraneal air, as to make it not only unfit for reſpiration, but able to extinguiſh their lamps and candles. And I have viſited mines, where inquiring of the diggers, whether thoſe hot exhalations, that compoſe their damps, did not ſometimes actually take fire within the bowels of the earth, they anſwered, that in ſome of their pits, and particularly in one they ſhew'd me, they did; when, the exhalation ſuddenly kindling, would make a report at the mouth of the pit like a muſquet; and that the flame would actually burn off the hair, and ſcorch the ſkins of thoſe workmen, who did not ſeaſonably get out of the pit, when the exhalation appeared to be near kindling; or did not ſuddenly fall down flat with their

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ned, and even twice in one day. And it ſeems to me, as well as to *Morinus*, very probable, that thoſe great quantities of rain, ſnow, and ſtorms, and, perhaps, ſome other meteors, taken notice of in winter, may rather conſiſt of theſe ſubterraneal ſteams, than the vapours and exhalations attracted by the ſun. For the ſun's heat is then very languid, and acts upon the ground only during the day time, which is very ſhort; whereas thoſe meteors, are generated indifferently at all hours of the day and night; and the ſky is often, for many days together, quite overcaſt with clouds, and the ſurface of the ground ſo bound up, that it will ſometimes freeze, even in the ſun-ſhine: whence 'tis not by much ſo likely, that the heat of the ſun, in the midſt of all theſe diſadvantages, ſhould elevate ſo great a plenty of exhalations and vapours, as is requiſite to compoſe the rain, ſnow and ſtorms, which ſometimes laſt almoſt all the winter, as that they ſhould be ſupplied by ſubterraneal ſteams, plentifully ſent up by the heat that continally reigns in the lower parts of the earth, and by traverſing the ſea, and at other vents, get up into the air.

And agreeably to this doctrine *Morinus* was told, by the maſters of the mines in *Hungary*, which are as deep as any I have ſeen or read of, that the miners were able, certainly, to foretel, ſooner than any other men, the tempeſts and ſudden alterations that were to happen in the air, from finding their lights burn blue, and from other manifeſt ſigns, in their grooves, of a large tempeſtuous damp aſcending from the lower parts of the earth, tho' the ſky above were clear, and the air calm. And an ingenious phyſician, who lived many years in *Cornwall*, told me, that many experienced fiſher-men aſſured him they often perceived fires ſhining in the night, ſometimes in one place, ſometimes in another, which were ſuppoſed to be kindled by the ſulphureous and other ſubterraneous exhalations; and that, when they ſaw thoſe fires, eſpecially if any number appeared in ſeveral places; even ſuch as were well accquainted with the coaſt, would not continue long out at ſea, but rather quit an opportunity of catching fiſh, than not make haſte to ſhore; having often obſerved, that bold and unexperienced mariners, by ſlighting theſe ſigns, were, in a few hours, caught in a tempeſt.

And ſome years ſince, upon the *Iriſh* coaſt, near a ſtrong fortreſs, called *Duncannon*, where many of his majeſty's ſhips lying at anchor, no danger from the wind being apprehended, there ſeemed ſuddenly to aſcend out of the water, not far from them, a black cloud, in ſhape and bigneſs like a barrel, which mounting upwards, was ſoon followed, as the moſt experienced pilot foretold, with ſo hideous a ſtorm, as forced thoſe ſhips to put again to ſea. And this account was both written by the principal officers of the ſquadron, to their ſuperiors in *England*, and given ſoon after it happened, by the chief of thoſe eye-witneſſes, and parti-

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PHYSICS. cularly by the pilot, to a very near kinſman of mine, who commanded the land forces in that country.

'Tis alſo ſaid, that not far from the city of *Buda*, there is a hot ſpring, called purgatory, which the waters of the *Danube* it ſelf are not able to keep cool; nay, within the very banks, betwixt which that great river runs, there boil up ſprings, which in their lower parts are intolerably hot. And having heard of a ditch in the north of *England*, whence not only ſubterraneal ſteams, but thoſe ſo ſulphureous as to be eaſily inflammable, conſtantly and plentifully aſcended into the air, I inquired about it of the miniſter of the place, who was well verſed in mines; and he atteſted the truth of the relation upon his own knowledge. It was alſo confirmed to me by a very ingenious gentleman, who went purpoſely to viſit this place, and found it true, that a lighted candle, being held where the exhalation iſſued out, would give fire thereto, and make it actually flame for a conſiderable time. And as this place was but lately taken notice of, there may probably be very many others, yet undiſcovered, that ſupply the air with ſtore of mineral exhalations, proper to generate fiery meteors and winds. A great ſearcher after mines told me, 'tis very uſual, in ſome places, where he is concerned in that affair, to ſee certain great fires moving in the air, which the diggers call dragons. And the *Ruſſian* emperor's phyſician inform'd me, he had obſerv'd, in winter, a river in *Muſcovy*, where, tho' the reſt of the ſurface was frozen, there was a part of it near a mile long, that remain'd uncovered with ice, which, probably, was kept from being generated by thoſe ſubterraneous exhalations; ſince, he ſays, he ſaw them aſcend up all the way like the ſmoak of an oven. And in caſe the matter of fact delivered by *Olaus Magnus* be true, concerning the ſtrange thaws that ſometimes happen, with a terrible noiſe, in the great lake *Veter*, thoſe wonderful phenomena may not, improbably, be aſcribed to the large aſcent of hot ſubterraneal ſteams, which ſuddenly cracking thick and ſolid ice, in many places at once, produce the hideous ſounds, and the haſty thaw he ſpeaks of. And this ſuſpicion may be countenanced from hence, that before theſe ſudden thaws, the lake begins, with great noiſe, to boil at the bottom; and alſo from what is related by a more authentic writer, the Jeſuit *Martinius*, who declares, that at *Pekin*, the capital of *China*, 'tis very uſual, after the rivers and ponds have continued hard frozen over, during the winter, for the thaw to be made in one day; which, ſince the freezing of the waters, as he tells us, required many, makes it very probable, that the ſudden thaw is effected as he alſo inclines to think, by ſubterraneal ſteams; which may well be ſuppoſed exceeding large, and to diffuſe themſelves every way to a very great extent, ſince they are able ſo ſoon to thaw the rivers and ponds of a large territory: and, which makes greatly for our purpoſe, they begin, contrary to vulgar thaws, from the bottom upwards.

Since then the lower parts of the earth, ſend up great plenty of exhalations and vapours to the upper, 'tis obvious, that as in ſeveral places theſe

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theſe ſteams get into the air, either thro' vents, or by growing ſtrong enough to force themſelves a paſſage; ſo in moſt others, where the aſcending ſteams find no commodious vents, or are too faintly driven up to force themſelves a paſſage, they muſt be repreſs'd or detained below the ſurface of the earth, which has its pores in winter uſually block'd up with ſnow or rain, or its ſurface conſtringed and hardned with ice or froſt; ſo that theſe exhalations being pent in, and continually receiving freſh ſupplies from beneath, 'tis no wonder, if they ſhould warm deep cellars and wells, where they are thus detained: and therefore our huſbandmen ſpeak rationally, when they ſay, that the ſnow keeps the ground warm. Dr. *Smith*, the learned *Engliſh* ambaſſador to *Moſcow*, makes it to be one of the principal reaſons of the great fertility of the country thereabout, that, during almoſt all the winter, the ground is to a great height covered with ſnow; which not only enriches it by the fertilizing ſalt the earth gains from the ſnow, when that comes to be melted; but alſo contributes to its improvement, by obſtructing the pores, at which the nitro-ſulphureous, and other uſeful corpuſcles, that are ſent up by the ſubterraneal heat, would eaſily get away. And the *Ruſſian* emperor's phyſician has aſſured me, that about *Moſcow*, where the ſurface of the ground is far more bound up in winter, than 'tis in theſe parts; and where they keep their cellars much cloſer; the ſubterraneous exhalations being hinder'd from flying abroad, will, in time, multiply ſo faſt, that upon the unwary opening of their doors, which have been long kept ſhut, there would ſally out a very thick warm ſmoak, which has ſometimes brought men in danger of ſuffocation. PHYSICS.

I muſt not, however, conceal an experiment or two I have met with, which ſeem to ſhew, that ſubterraneal places are really hotter in winter, than in ſummer.

The learned jeſuit *Zucchius*, aſſures us, that having kept a good ſeal'd weather-glaſs, for three years together, in a cellar, he found the water to riſe by the coldneſs of the ambient air in the ſummer, and to be depreſſed by the rarifaction of it in the winter; which ſeems undeniably to prove that whatever be the reaſon of it, the heat in ſubterraneal places is indeed greater in winter than in ſummer. And another jeſuit affirms, he found by a weather-glaſs, that a well at the place where he lived, was colder in ſummer, and hotter in winter.

'Tis not, however, univerſally true, that cellars, and other ſubterraneal places, are hotter in winter than in ſummer. For my own obſervations, made in a cellar, with a ſealed weather-glaſs, manifeſt the contrary. I would, therefore, make a diſtinction of ſubterraneal places; for ſome are deep, as the beſt ſort of cellars; others deeper yet, as the *Hungarian* mines, mention'd by *Morinus*; and ſome again are but ſhallow, as many ordinary cellars and vaults: of theſe three ſorts of ſubterraneal places, the deepeſt of all do not ſeem to grow hot and cold, according to the ſeveral ſeaſons of the year, as the vulgar doctrine of antiperiſtaſis requires; but are, according to ſome minerialiſts, continually hot: the

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PHYSICS. ſhallower ſort of ſubterraneal places, being fenced, from the outward air, are not ſo ſubject to the alterations of it, as open places; yet, by reaſon of their vicinity to the ſurface of the earth, they are ſo far affected with the mutations, whereto the outward air is liable, in ſeveral ſeaſons of the year, that in winter, though they be warm in reſpect of the colder air abroad, yet they are really, as far as I have try'd, colder in very cold weather, and leſs cold in warm weather. Thus the *Polonian* nobleman, formerly mentioned, aſſured me, that, in his country, ſharp winters would freeze ſmall beer in cellars, that were not very deep, tho' it continued fluid in thoſe that were. And the anonymous jeſuit lately mentioned, acknowledges, he found but little difference between the temperature of the water in the well he examined in ſummer, and in winter, tho' it were a conſiderably deep one; and adds, that at *Florence*, when the ſubterraneal vaults are ſhallower, the air is obſerved to be colder in winter than in ſummer; tho' the contrary has been found in the deep cellars at *Rome*. So that the loweſt ſort of ſubterraneal cavities being, for ought apperas, perpetually hot; and the upper or ſhallower ſort of them, being colder, not hotter in cold weather than in warm; 'tis about the temperature of the middle ſorts of them, ſuch are the deeper and better cellars, that the queſtion remains to be determined.

We muſt next conſider, that 'tis not ſo eaſie a matter as philoſophers think, to make, with the weather-glaſſes hitherto in uſe, an experiment to our preſent purpoſe, that ſhall not be liable to ſome exception, eſpecially if the cellar, or well, be very deep. For the gravity of that thick and vapid ſubterraneal air, and the greater preſſure which the air may there have, by preſſing in an atmoſpherical pillar, lengthened by the depth of the cellar, may, in very deep cavities, as well alter the height of the water in common weather-glaſſes, as heat and cold; and ſo make it uncertain, when the mutation is to be aſcribed to the one, and when to the other; or at leaſt very difficult to determine diſtinctly, what ſhare is due to the preſſure, and what to the temperature of the air. And this uncertainty is much increaſed, by conſidering, that not only in places where the heights of the atmoſpherical cylinders differ, the preſſure of the air upon the ſtagnant water in the weather-glaſſes may do ſo too; but even in the ſame place the inſtrument remaining unmoved, the preſſure of the atmoſphere may, as I have often obſerved, ſoon alter conſiderably, and that without any conſtant and manifeſt cauſe; ſo that an erroneous eſtimate of the temperature of the air, can ſcarce poſſibly be avoided, without the help of a ſealed weather-glaſs, where the included liquor is ſubject to be affected by heat and cold, and not preſſure of the air. To apply this to *Zucchius* his experiment; unleſs he made his obſervations with the aſſiſtance of a ſealed weather-glaſs, it may be ſuſpected, that he might accidentally find the water in a common one, (which he appears to have us'd, as, probably, knowing no other,) to be higher, when he look'd on

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it in ſummer, than in winter; not becauſe really the ſubterraneal air was colder in the former ſeaſon, than in the latter; but becauſe the atmoſphere chanced then to be heavier. And conſidering in how few hours, I have ſometimes obſerved the quick-ſilver, both in a good barometer, and even in an unſeal'd weather-glaſs furniſhed with quick-ſilver, to riſe almoſt an inch perpendicularly, without any manifeſt cauſe proceeding from cold; I cannot think it impoſſible, that in long weather-glaſſes, furniſhed only with water, or ſome ſuch liquor, the undiſcerned alterations of the atmoſphere's preſſure, may produce very notable ones in the height of the water in ſuch inſtruments. But farther, *Zucchius* having, for ought appears, made his obſervations only in one place, we are not ſure, that it was not one of thoſe whereon ſubterraneal exhalations have a peculiar and conſiderable effect; as happens in the great and ſudden thaws, that ſometimes begin from the bottom, and thereby argue their being produc'd by ſteams, aſcending from the lower parts of the terreſtrial globe; which may be farther confirm'd by what was formerly noted of the ſudden damps happening in mines. But what is of the moſt importance, the learned *Maignan* had the ſame curioſity as *Zucchius*, but with very different ſucceſs; and, therefore, this inquiſitive perſon rejects the vulgar doctrine of antiperiſtaſis, upon account of two experiments. For, firſt, he ſays, he found with a thermometer, that when, in winter, a cold northerly wind froze the water without doors, it was no leſs cold in wine-cellars, than in the ſame ſeaſon, and at the ſame hour of the day in his ſtudy; only the paper-ſhuts of his window, that regarded likewiſe the north, being put to. And theſe cellars too, it ſeems, were of the very beſt of the kind, wherein the greateſt cold was felt ſummer. But his next experiment is yet more conſiderable. "I found," ſays he, "with a very exact "thermometer, that the greateſt coldneſs of ſome excellent wine-vaults, "in the moſt vehement heat of the ſummer, was not equal to that they "had in the winter; tho' the former ſeem'd much the moſt ſevere to ſenſe."

Thus far our learned author, who, ſeeming by the mathematical part of his *Perſpectiva Horaria*, to be an accurate and induſtrious obſerver, we may oppoſe his experiment to that of *Zucchius*, which it flatly contradicts; and, therefore, ſince the depth of the cellar is of great moment in experiments of this nature; ſince alſo the particular parts of the place or ſoil, where the cellars, or other cavities, happen, may, in ſome caſes, deſerve to be conſider'd; and ſince, laſtly, neither *Zucchius*, or *Maignan*, ſeem to have been aware of the differing weights of the atmoſphere in the ſame place; I ſhall determine nothing poſitively, till the experiment has been carefully made, for a competent ſpace of time, in ſeveral places, and that not with common weather-glaſſes, but with ſealed thermometers.

Having thus ſhewn, that tho' experience be ſo confidently appeal'd to, by the maintainers of antiperiſtaſis, yet nothing conſiderable to favour

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PHYSICS. favour their cauſe, has been hitherto drawn from thence; I ſhall next ſhew, that it bears witneſs againſt them.

I took an iron rod, about the bigneſs of a man's finger, having at one end of it a very broad and thick piece of iron, ſhaped almoſt like a ſpatula, that the quantity of the matter might, upon the ignition of the iron, make the heat very conſiderable: then cauſing this thick end to be made red hot in the fire, and having ſuddenly quench'd it in cold water, I could not perceive, that the other end of the rod, by which it was held, grew at all ſenſibly hot, as a favourer of antiperiſtaſis would have expected it ſhould do, to a very high degree; as preſuming, that the innumerable particles of heat, which ſwarmed in the compact body of the red hot part of the iron, muſt, to fly the cold of the water, retire in throngs towards the other extreme of the iron, and make it exceedingly hot. And leſt any pre-exiſtent warmth ſhould hinder me from perceiving an increaſe of heat, in caſe any were produced in the handle of the iron, I caus'd it, the next time the trial was made, to be kept in cold water, yet even then the immerſion of the broad ignited end in the cold water, brought as little ſenſible heat to the other end, as it had done before: and having caus'd the experiment to be made by another, it ſucceeded with him as it had done with me.

Again; I took an excellent ſeal'd weather-glaſs, fourteen inches long, furniſhed with good ſpirit of wine, and having provided an open mouth'd glaſs, of a convenient ſhape and ſize, and fill'd it to a due height with common water, I ſo ordered the matter, that the ſtem of the thermometer being ſupported by the cork, into which, by a perforation, it was inſerted, when the glaſs was ſtopp'd by the cork, the whole ball of the thermometer was immers'd in the water, that fill'd the wide-mouth'd glaſs, and no where touched, either the bottom or the ſides of the glaſs, ſo that the ball was every way ſurrounded with water. The inſtrument being thus prepar'd, we obſerv'd at what ſtation the ſurrounding cold water had made the tinged ſpirit reſt in the thermometer; and than having proved a fit proportion of warm water, in a proper veſſel, I remov'd the inſtrument into it, and plac'd it ſo, that the liquor reach'd to a convenient height on the outſide of the open mouth'd glaſs: but tho' I carefully watch'd, whether the heat of the external water, would increaſe or ſtrike inwards the cold of that water, which immediately encompaſſed the ball of the weather-glaſs; yet I perceived no ſuch matter, the tinged ſpirit in the ſtem keeping its ſtation, till the heat having, by degrees, been diffus'd thro' the cold water, by the intervention of that, now warmed, the tinged ſpirit in the thermometer began to aſcend,

And to reduce the other part too, of the doctrine of antiperiſtaſis, to the determination of an experiment, the ſame thermometer was plac'd in the ſame wide-mouth'd glaſs, juſt after the former manner, only inſtead of the cold water, that which immediately ſurrounded the glaſs

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glaſs was warm; and when the warmth had impell'd up the ſpirit, till its aſcent began to be very ſlow, I immers'd the inſtrument to a convenient depth in a veſſel, that contain'd ſome very cold water, mixed with ſeveral pieces of ice. But it did not appear to me, that the heat of the water, which immediately encompaſſed the ball of the weather-glaſs, was at all increaſed, by that liquor's being ſurrounded with water exceeding cold; for the languid motion of the ſpirit upwards, was not hereby ſo much as ſenſibly accelerated, but rather the aſcent was, by the chilneſs of the contiguous water, quickly check'd, and the aſcending ſpirit ſoon brought to ſubſide again. And for fuller ſatisfaction in the phenomena of this, and he former experiment, I obſerved them more than once. PHYSICS.

XXVI.

Mr. Hobbs's doctrine of cold examin'd.

Mr. *Hobbs*'s theory of cold, appears ſo inconſiderately choſen, and ſo ſlightly made out, that I ſhould not think it deſerved a particular examination, but for the grand air wherewith it is propoſed. For he talks ſo much of demonſtrations, and ſets himſelf ſo far above the moſt eminent writers, that the unwary may miſtake his confidence for evidence; and rather accuſe their own underſtanding, than diſtruſt his doctrine.

Mr. *Hobbs*'s doctrine, ſo far as relates to cold, is in ſubſtance this. The motion of the ſun between the tropics, driving the air towards that part of the earth's ſurface, which is perpendicular under it, makes it ſpread it ſelf every way; and the velocity of this expanſion of the air, grows gradually greater, as its circles parallel to the *Æquator* become leſs. Wherefore this expanſive motion of the air, drives before it ſuch of its parts, as are in its way continually towards the poles more ſtrongly, as its force comes to be more united; that is, as the circles parallel to the *Æquator* are leſs, or the nearer it comes to the poles of the earth. In thoſe places, therefore, which are nearer to the poles, there is a greater cold, than in thoſe which are more remote from them. Now this expanſion of air upon the ſuperficies of the earth, from eaſt to weſt, by reaſon of the ſun's perpetual arrival to the places which are ſucceſſively under it, makes it cold at the time of the ſun's riſing and ſetting; but as the ſun comes to be more perpendicular to thoſe cooled places, ſo by the heat, which is generated by the ſupervening ſimple motion of the ſun, that cold is again remitted, and can never be great; becauſe the action, by which it was generated, was not permanent. This, therefore, is a poſſible cauſe of cold in thoſe places, that are near the pole, or where the obliquity of the ſun is great.

Water may be congealed by cold, from the action of the air in thoſe parallels which rake the ſuperficies of the earth; and that with a motion ſo much the ſtronger, as the parallel circles towards the poles grow leſs. From whence muſt ariſe a wind, which will force together the upper

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PHYSICS. upper parts of the water, and withal raiſe them a little, weakning their endeavour towards the center of the earth. And from their endeavour towards the center of the earth, joyned with the endeavour of the ſaid wind, the upper parts of the water will be preſſed together and coagulated; that is to ſay, the top of the water will be ſkinned over and hardened; and ſo again the water next the top, will be hardened in the ſame manner, till at length the ice be thick. And this ice being now compacted of little hard bodies, muſt alſo contain many particles of air received into it. And as rivers and ſeas, ſo, in the like manner, may the clouds be frozen. For when, by the aſcending and deſcending of ſeveral clouds at the ſame time, the air intercepted between them, is, by compreſſion, forced out, it rakes, and, by degrees hardens them. And tho' thoſe ſmall drops, which uſually make clouds, be not yet united into greater bodies, yet the ſame wind will be made; and by it, as water is congeal'd into ice, ſo will vapours in the ſame manner be congeal'd into ſnow. From the ſame ſame cauſe it is, that ice may be made by art, and that not far from the fire; which is done by mixing ſnow and ſalt together, and by burying it in a ſmall veſſel full of water: for, when the ſnow and ſalt, which contain a great deal of air, are melting, the air which is preſſed out every way in wind, rakes the ſides of the veſſel; and as the wind by its motion rakes the veſſel, ſo the veſſel, by the ſame motion and action, congeals the water within it.

We find by experience, that cold is always more remiſs in places where it rains, and, *cæteris paribus*, where the weather is cloudy, than where the air is clear. For, in clear weather, the courſe of the wind, which raked the ſuperficies of the earth, as it is free from all interruption, ſo alſo it is very ſtrong. But when ſmall drops of water are either riſing or falling, that wind is repell'd, broken, and diſſipated by them; and the leſs the wind is, the leſs is the cold.

We find, alſo, by experience, that in deep wells the water freezeth not ſo much, as upon the ſuperficies of the earth. For the wind, by which ice is made, entring into the earth, loſeth ſome of its force, tho' not much; ſo that if the well be not deep, it will freeze; but if it be ſo deep, that the wind, which cauſeth cold, cannot reach it, 'twill not freeze.

We find, moreover, by experience, that ice is lighter than water; the cauſe whereof is manifeſt from hence, that the air is received in, and mixed with the particles of the water, in the act of congelation.

To examine this theory, we may, in the firſt place, obſerve, that Mr. *Hobbs*'s notion of cold, is not accurately delivered. It may be well queſtion'd, whether the external tendency of the ſpirits and fluid parts of the bodies of animals, neceſſarily proceeds from, and argues heat; ſince in our pneumatical engine, when the air is withdrawn from about an included viper, there is a great intumeſcence, and, conſequently, a greater endeavour of the fluid parts of the body outwards, than we

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ſee made by any degree of heat in the ambient air, uſually produced by the ſun. But Mr. *Hobbs* tells us, that to cool, is to make the external parts of the body endeavour inwards; yet our experiments tell us, that when a very high degree of cold is introduced, not only into water, but into wine, and other liquors, there is a plain ſwelling, and, conſequently, an endeavour outwards of the parts of the body cooled. And, certainly, cold having an operation upon a great multitude and variety of bodies, as well as upon our organs; he that would give a ſatisfactory definition of it, muſt take into conſideration ſeveral other effects, beſides thoſe it produces on human bodies. And even in theſe, he will not eaſily prove, that, in every caſe, any ſuch endeavour inwards from the ambient ætherial ſubſtance, as his doctrine ſeems to ſuppoſe, is neceſſary to the perception of cold: ſince as the mind perceives ſeveral other qualities, by various motions in the nervous or membranous parts of the organ; ſo cold may be perceived, either by the decreaſe of the agitation of the parts of the object, with regard to thoſe of the organ; or elſe by a different impulſe of the ſenſitive parts, occaſioned by ſome change made in the motion of the blood or ſpirits, upon the decay of that motion; or by the turbulent velocity of thoſe excrementitious ſteams, which, when the blood circulates as quick, and the pores are kept as open as before, are diſſipated by inſenſible tranſpiration. PHYSICS.

'Tis a known thing, that many hyſterical patients complain of a great coldneſs in their head, or other parts, and ſometimes too when they ſeem to be otherwiſe hot. And I know a nobleman, who falling, as frequently he has done, into a fit of the ſtone, feels an univerſal coldneſs over his whole body, like that which begins the fit of an ague. And tho' he aſſures me, that the ſtones, which he uſually voids, are but very ſmall; yet, whilſt the fit continues, he cannot, by cloaths, or almoſt any other means, keep himſelf warm.

Hence it appears, there may be other ways, beſides thoſe already mentioned, of perceiving cold, tho' the outward parts of our bodies are not preſt inwards. Mr. *Hobbs* declares, that he who would know the cauſe of cold, muſt find by what motion the external parts of a body endeavour to retire inwards; but this ſeems an inconſiderable direction. For, in compreſſions that are made by ſurrounding bodies, there is produced an endeavour inward of the parts of the compreſt body, tho' not cold, but ſometimes heat be thereby generated. And, I hope, Mr. *Hobbs* will not object, that in this caſe the parts do not retire, but are thruſt inwards; ſince, according to him, no body at all can be moved, but by another contiguous and moved. And this may ſuffice to ſhew, that the notion of cold, in general, is not ſo eaſie to acquire as many think; and therefore it needs be no wonder, that it hath not been accurately propoſed by Mr. *Hobbs*. In the next place, the cauſe he aſſigns, why a man can blow hot or cold with the ſame breath, is very queſtionable; becauſe he ſuppoſes in part of the breath

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PHYSICS. ſuch a ſimple motion, as he calls it, of the ſmall particles of the ſame breath, as he will not eaſily prove; and becauſe that without the ſuſpected ſuppoſition, I could give a more probable account of the phenomenon, if I had not ſome ſcruples about the matter of fact itſelf: for tho' I am not ſure, that farther trials may ſhew the wind or breath, blown out at the middle of the compreſſed lips, to have in it ſuch a real coldneſs, as men generally aſcribe to it; yet hitherto ſome trials incline me to ſuſpect, that in eſtimating the temper of the wind produc'd, our ſenſes may impoſe upon us. For having taken a very tender ſeal'd weather-glaſs, and blown upon it thro' a long, ſlender glaſs-pipe, to be ſure that my breath ſhould iſſue out in a ſmall ſtream; by this wind beating upon the ball of the weather-glaſs, I could not make the included ſpirit of wine ſubſide; but it manifeſtly aſcended, tho' the wind, that I preſently blew thro' the ſame pipe, ſeem'd ſenſibly cold, both to the hand of by-ſtanders, and to my own, which was at that time, more than ordinarily cold. But whatever be the cauſe of the effect, there are ſeveral things that make Mr. *Hobbs*'s hypotheſis of cold unſatisfactory. For the grand cauſe he aſſigns of cold, and its effects, is wind; which, according to him, is air mov'd in a conſiderable quantity, and that either forwards only, or in an undulating motion: and he tells us too, that when the breath is more ſtrongly blown out of the mouth, then the direct motion is prevalent (over the ſimple motion) which, according to him, makes us feel cold; for, ſays he, the direct motion of the breath or air is wind, and all wind cools or diminiſhes former heat. He adds, that not only great, but almoſt any ventilation, and ſtirring of the air, refrigerates. But,

1. There are very hard froſts, not only continued, but often begun, when the air is calm and free from winds: and high and boiſterous ſoutherly winds are not here found to be near ſo cold, as far weaker winds that blow from the north-eaſt.

2. If Mr. *Hobbs* teaches, 'tis the direct motion of the ſtream of breath, if more ſtrongly blown out, that makes us feel cold, he is obliged to aſſign a reaſon, why in an æolopile with a long neck, the ſtream that iſſues out, tho' often far ſtronger than that, which is made by compreſſing the lips, at a conſiderable diſtance from the orifice it iſſues out of, is not cold, but hot.

3. Mr. *Hobbs* elſe-where teaches, that when in our engine, the pump has been long employ'd to exhauſt the receiver, there muſt be a vehement wind produc'd in that receiver; yet by one of our experiments it appears, that for all this, in a good ſeal'd weather-glaſs plac'd there, before the included air began to be emptied, there was no ſign of any intenſe degree of cold produc'd by this ſuppos'd wind; ſo that either the wind is but imaginary, or elſe Mr. *Hobbs* aſcribes to winds, a power of cooling, that does not belong to them.

4. We find by experience, that in hard froſts water will freeze, not only tho' there be no wind ſtirring in the ambient air, but tho' the liquor

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liquor be kept in a cloſe room, where, if the wind were high abroad, it could not get admittance. And ſome experiments carefully made have aſſur'd us, that water ſeal'd up in one glaſs, and that glaſs ſuſpended in another carefully ſtopt, to keep out all adventitious air, may nevertheleſs be turn'd into ice. PHYSICS.

5. We found by other experiments, that a frozen egg, tho' ſuſpended in, and perfectly ſurrounded with water, where no wind cou'd come at it, wou'd be every way cruſted over with ice; in which caſe there is no probability, that the ice ſhould be generated according to the way propos'd by Mr. *Hobbs*. For he will ſcarce prove, that a wind pierc'd the ſhell and cloſer coats of the egg to get into the contain'd liquors, and freeze them: and a more unlikely aſſertion it would be, to pretend, as he who maintains Mr. *Hobbs*'s doctrine muſt, that ſo very little air, if there be any, as is mix'd with the juices of the egg, can by the cold, which does not expand air, be turned into a wind ſubtile enough, freely to penetrate the ſhell and coats of the egg, and able to diffuſe itſelf every way, and turn, on every ſide, the neighbouring water into ice; and all this, tho' it appears not, by bubbles breaking thro' the water, that any adventitious air comes out of the egg at all: and ſuppoſing ſome ſuch were contain'd in the egg, yet what ſhadow of reaſon is there to conceive, that the air which was ingaged in, and ſurrounded with the ſubſtances of the white, and the yolk of an egg, muſt needs be a wind; ſince, according to Mr. *Hobbs*, wind requires a conſiderable motion of moſt of the parts of the air mov'd the ſame way; and according to him alſo a body cannot be put in motion, but by another body contiguous and mov'd?

6. Mr. *Hobbs*, indeed, affirms that all wind cools, but is ſo far from proving that the higheſt degrees of cold muſt needs proceed from wind, that he does not ſhew all winds to be cool. Nor are we bound to believe it without proof; ſince wind being, according to him, but air mov'd in a conſiderable quantity, either in a direct or undulating motion, it does not appear how motion ſhould, rather than reſt, make air grow cold. For tho' it be true, that winds uſually ſeem cold to us, yet it is not univerſally true; ſince ſome, who have travelled into hot countries, and particularly the learned *Alpinus*, complains, that the winds coming to them in the ſummer from more torrid regions, have appear'd to be almoſt like the ſteam that iſſues out at the mouth of a heated oven. And 'tis ſaid, that the ſouthern winds near *Ormus*, have been ſometimes ſo hot, as at once to deſtroy an army. But even when the wind does feel cold to us, it may often do ſo but by accident; for the ſteams that iſſue out of our bodies being uſually warmer then the ambient air; and the more inward parts of our bodies themſelves, being very much hotter than it; the ſame cauſes that turn air into wind, put it into a motion, that both diſplaces the more neighbouring and more heated air, and alſo makes it pierce far deeper into the pores of the ſkin; whereby becoming ſenſible to

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PHYSICS. thoſe parts, that are ſomewhat more internal than the *Cuticula*, and far more hot; the air turn'd into wind ſeems to us more cold, than the ſtagnant air. Thus, tho' air blown thro' a pair of bellows upon one's hand, when 'tis in a moderate temper, will ſeem very cold; yet, that the ambient air is thus turn'd into wind, without acquiring ſuch a cold as is preſum'd, may appear by blowing the ſame air, with the ſame bellows, upon weather-glaſſes; for in doing this, we could not obſerve, that the wind beating upon them did ſenſibly cool either the air, or the liquor. Tho' 'tis not impoſſible, that in ſome caſes the wind may cool even inanimate bodies, by driving away a parcel of ambient air, impregnated with exhalations leſs cold, than the air that compoſes the wind. But this is no more than would be affected, if, without a wind, ſome other body ſhould precipitate out of the air, near the weather-glaſs, the warmer effluvia; eſpecially if the precipitating body introduce, in the room of the diſplaced particles, ſuch as may be juſtly term'd frigorific.

7. Nor can we admit, without a favourable conſtruction, Mr. *Hobbs*'s expreſſion, that all wind cools or diminiſhes former heat. For if we take heat in the moſt common acceptation; to make wind the adequate cauſe of cold, it muſt in many caſes do more than diminiſh former heat. Water, for inſtance, ready to freeze, is already actually cold in a high degree; yet the wind, according to Mr. *Hobbs*, muſt make this very cold liquor, ſtill more cold, before it can turn into ice.

The remaining part of Mr. *Hobbs*'s theory of cold, may now be ſoon diſpatch'd, the greateſt part of it being to ſhew, that there is an expanſion of the air, or a wind generated by the motion and action of the ſun: but why this wind thus generated muſt produce cold, I do not ſee that he proves; nor does his affirming, that it moves towards the poles, help the matter. For we have ſhewn, that wind is not ſufficient to produce far leſs degrees of cold, than thoſe felt in many northern regions; and there muſt be ſome other cauſe than the motion of the air, or ſteams driven away by the ſun, to make bodies, not in themſelves cold, become vehemently ſo in their paſſage. For Mr. *Hobbs* cannot, as other naturaliſts do, derive the coldneſs of freezing winds from the cold ſteams they meet, and carry along with them in their paſſage thro' cold regions; ſince then thoſe ſteams, rather than the wind, would be the cauſe of that vehement coldneſs and ſo it might juſtly be demanded, whence the coldneſs of thoſe cold exhalations proceeds. Beſides, 'tis very precarious, and contrary to obſervation, to imagine ſuch a wind, as he talks of, to blow whenever great froſts happen; ſince, as we noted before, very vehement glaciations may be obſerv'd, eſpecially in northern regions, when the air is calm and ſerene.

The account he gives of turning water into ice, is the moſt unſatisfactory I ever yet met with: in ſuppoſing that by the endeavour of the wind to raiſe the parts of the water, join'd with the endea-

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ſays that which is very far from ſatisfactory. For ice is often produced, where no wind can come to beat upon the upper parts of the water, and to raiſe them: and in veſſels hermetically ſeal'd, which exactly keep out air and wind, ice may be generated, as our experiments demonſtrate. And this alone were a ſufficient anſwer, ſince the whole explanation is built upon the action of the wind. But this is not all, for he ſhould have prov'd, that the upper parts of the water muſt be raiſed in congelation; eſpecially ſince oil, and ſeveral other liquors, are contracted by it. And what ſhew of probability is there, that by the bare endeavour of the wind, and the gravity of the ſuperficial parts of the water, there ſhould be any ſuch forcible compreſſion made, as he takes for granted? Yet this itſelf is leſs improbable than, ſuppoſing the uppermoſt parts of the water to be preſſed together, that preſſure ſhou'd be ſufficient to congeal them into ice. So bold and unlikely an aſſertion ſhould at leaſt have been countenanced by ſome plauſible reaſon, or parallel example. For I remember no inſtance, wherein any degree of compreſſion, that has been employ'd, much leſs ſo ſlight an one as this muſt be, conſidering the cauſes whence 'tis ſaid to proceed, can harden any liquor into ice. By filling a pewter veſſel with water, and when 'tis exactly clos'd, compreſſing it by blows of a hammer, till the water be reduc'd to penetrate the very pewter, we found not that ſo violent a compreſſion gave the water the leaſt diſpoſition to become a hard body. And as for the way Mr. *Hobbs* advances of increaſing the thickneſs of ice, 'tis very difficult to conceive, how a cake of ice on the top of the water, being hard frozen to the ſides of the containing veſſel, and thereby ſeparating the included water and the external air, the wind that cannot come to touch the water, becauſe of the interpoſition of the hard and rigid ice, ſhould yet be able, ſometimes at the depth of ten feet, or more, to beat upon the ſubjacent water, and turn it into ice. And it is yet more difficult to conceive, how the wind muſt do all this, when, as we lately noted, the water very often gradually freezes downwards, to a great depth, in places where the wind cannot come at all. And as to what Mr. *Hobbs* further teaches, that the ice muſt contain many particles of the air receiv'd into it, we have formerly ſhewn, how erroneouſly he diſcourſes about thoſe icy bubbles.

The reaſon he aſſigns of the freezing of water with ſnow and ſalt, is as little ſatisfactory as the reſt of his theory. He affirms, without proving it, that ſnow and ſalt have in them a great deal of air; and very precariouſly aſſerts, that this air muſt needs be preſt out every way in wind, and ſo rake the ſides of the veſſel: 'tis ſtrange, that far more diligent obſervers than Mr. *Hobbs*, ſhould take no notice of any ſuch wind, if any ſuch wind there were. But this is yet leſs ſtrange than that, this wind muſt ſo rake the ſides of the veſſel,

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PHYSICS. veſſel, as to make the veſſel by the ſame motion and action congeal the water within it. For what affinity is there between a wind, paſſing along the outſide of a glaſs, altogether impervious to it, and the turning a fluid body, included in that glaſs, into a hard and brittle one? The wind, indeed, may perhaps, if it be ſtrong, a little ſhake or agitate the particles that compoſe the glaſs, and thoſe may communicate ſome of their motion to the contiguous parts of the water; but why all this muſt amount to the turning of that water into ice, is more, I confeſs, by far, than I can apprehend. Tho' you long blow upon a glaſs of water with a pair of bellows, where there is not an imaginary wind, like Mr. *Hobbs*'s, but a real and manifeſt one; yet the water will be ſo far from freezing, that it will ſcarce be cool'd. And if ſea-ſalt contain ſo much air, by vertue of which, it, as well as the ſnow, produces ſo intenſe a degree of cold; how chance that, being diſſolv'd in a little water without ſnow, it does not produce a conſiderable degree of cold? Beſides, in the experiment we made of freezing water up in ſeal'd bubbles; tho' the bubbles were ſuſpended in other glaſſes, whoſe ſides no were touched them, and the remaining part of whoſe cavities were fill'd, ſome with air, and ſome with uncongelable liquors; what likelihood is there, that Mr. *Hobbs*'s inſenſible wind ſhould be able to occaſion ſo many ſucceſſive rakings thro' different bodies, as there muſt be, to propagate the congealing motion of the wind, thro' the firſt glaſs, to the included air or liquor, and thro' that new medium to the glaſs immediately containing the water, and thro' that to the innermoſt parts of the water ſeal'd up? It might be further objected, if it were worth while, that Mr. *Hobbs* does not ſo much as offer at a reaſon, why ſpirit of wine, *Aqua fortis*, or even brine, if it be of the ſtrongeſt ſort, are not either by this mixture, or (here in *England*) by the wind in the open air, turn'd into ice.

The reaſon why cold is more remiſs in rainy or cloudy weather, than in that which is more clear, ſeems to be no better aſſign'd by Mr. *Hobbs*, than by others who have written before him: for I have ſeen great and laſting froſts in cloudy, and ſometimes very dark weather: and what he talks of the wind's being more ſtrong in clear weather, than in cloudy, is of no great importance; ſince common experience ſhews, that in clear weather the air may be very cold, and the froſt very great, where no wind is felt to rake, as he would have it, the ſurface of the earth. Nor does experience bear witneſs to what he raſhly pronounces, that the leſs is the wind, the leſs the cold. There are but two phenomena more, which Mr. *Hobbs* here pretends to explain: the one is, that in deep wells the water freezes not ſo much, as upon the ſurface of the earth. But Mr. *Hobbs* has not rightly aſſigned this, to the wind's entring more or leſs into the earth, by reaſon of the laxity of its parts; ſince it is very improbable, that the wind ſhould not, as he ſays it does not, loſe much of its force by entring into the earth at its pores, and other leſſer cavities, to ſo great

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great a depth as water lies in several wells, subject to freezing: besides, experience teaches us, that wells may be frozen, tho' their mouths be well covered, and the wind thereby kept from approaching near the included water; and very many wells, that are subject to freeze, when northerly and easterly winds reign, will likewise be frozen in very cold winters, whether any winds blow, or not. PHYSICS.

The last phenomenon Mr. *Hobbs* attempts to solve, is that of ice being lighter than water. The cause whereof, says he, is manifest from what I have already shewn; namely, that the air is receiv'd in, and mixed with the particles of the water whilst congealing. But that this is not the true reason, may be argued from hence, that if a conveniently shap'd glass-vessel be quite fill'd with water, and expos'd, either unseal'd or seal'd, to congelation, the ice will contain numerous bubbles, which, at least in the seal'd vessel, cannot by Mr. *Hobbs*, (who will not say that glass is pervious to the air) be pretended to proceed from bubbles, that got from without into the water, whilst it was congealing. And we have manifested, by particular experiments purposely made, how little of air there is, even in those bubbles that are generated in ice, made in vessels, where the air was not kept from the water.

Thus we have seen, that most of the particulars advanced in Mr. *Hobbs*'s theory of cold, are either precarious or erroneous; and were they neither, yet the whole would, I fear, prove very insufficient. For this learned author has past by far the greatest part even of the more obvious phenomena of cold, without attempting to explain them, or to shew, so much as in a general way, that he had consider'd them, and thought them explicable by his hypothesis.

XXVII.

I will not undertake to prove the nature of cold to be privative, but think it easy to shew, that the arguments produced for its being positive, are not conclusive. 'Tis said in the first place, that if cold be but a privation, it cannot be the object of sense. To clear this, I must observe something about sensation in general. That, then, which produces in the mind those perceptions, which we call sensations of outward objects, is the local motion, caused by means of their action, upon the outward organs, in some internal part of the brain, to which the nerves belonging to those organs correspond; and the diversity of sensations may be referr'd to the different modifications of those internal motions of the brain, either according to their greater or less celerity, or other circumstances; as we see in the variety of sounds, some whereof are grave, some sharp, some harmonious and pleasant, some jarring and offensive; yet all of them proceed from the variations of those impulses, which the air, put into motion by sonorous bodies, gives to the

Whether cold be a positive, or privative thing.

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PHYSICS. the ear. As the air then is differently affected by a very grave ſound, and a very acute one; tho' the former proceed from the want of that celerity of motion in its undulations, which is to be found in the latter; whence it approaches the nature of reſt; ſo in the organ of feeling, perception may be produced upon the contact of a cold body, very different from that which is cauſed by the contact of a hot one: and this, tho' the thing perceived, and by us called coldneſs, conſiſts but in a leſs agitation of the parts of a cold body, than of thoſe of the hot one, in reſpect to our organs of feeling. And ſince it is manifeſt, that bodies communicate their motion to thoſe they happen to act upon, and loſe of their own by ſuch communication; if a man take a piece of ice in his hand, the agitation of the particles of the organ, will be communicated to the corpuſcles of the ice, which, upon that account, quickly begins to thaw; and the contiguous parts of the hand, loſing of the motion acquired by the ice, there needs nothing elſe to leſſen the agitation they had before: and no more than this decreaſe of agitation is required, to occaſion in the mind ſuch a new and different perception, as men have tacitly agreed to call coldneſs.

'Tis farther obſervable, that the organs may be ſo accuſtomed to be affected after a certain manner by thoſe external objects, whoſe operation on them is ſo very familiar, that the privation, or bare diminution of the wonted operation, leaves their parts in a different diſpoſition from what they were in formerly; which change in the organ will be attended with a perception of it in the mind. Thus, tho' darkneſs be confeſſedly a privation of light, and the degrees of it, gradual diminutions of light; yet the perceptive faculty, by means of the eye, may well be ſaid to perceive both light and darkneſs; that is, both a poſitive thing, and the privation of it. And it is obvious, that the motion of a ſhadow, or a gradual privation of light, is plainly, and without difficulty, diſcoverable by the eye. And to ſhew, that there is on theſe occaſions an apparent change made in the organ of viſion, we need but deſire a perſon in the day-time, to look towards an enlightned window, and then towards an obſcure part of the room; ſince when he does the latter, for want of ſuch a degree of light as before came in at the pupil, that circle will grow manifeſtly larger. Thus, when a man comes out of the ſun-ſhine, (where the pupil contracts, to ſhut out an exceſſive light, which would be offenſive to the organ,) into a darkned room; it will be ſome time before he can clearly ſee others there, whoſe pupils have had time to be ſo enlarged, as to let in light enough to render objects viſible to them, which are not ſo to him, whoſe pupils are yet contracted by the light they were juſt before expos'd to.

The next argument to be conſider'd is this. When we put our hands into cold running water, in the winter ſeaſon, the cold we perceive therein cannot be called a mere privation; and there is a great difference

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ference between feeling water cold, and the feeling of it not hot: but ſuppoſing the ſame water to be frozen, 'twill doubtleſs then feel colder; and will any one ſay, that this is nothing but to feel it leſs hot? But it was not hot before, how, therefore, could it become leſs hot? To this we reply, that the organs of ſenſe, conſider'd in themſelves, only receive impreſſions from outward objects, but perceive not what is the cauſe and manner of thoſe impreſſions; the proper perception of cauſes belonging to a ſuperior faculty, which judges whence the alterations made in the organs do proceed. Thus the eye repreſents a ſtrait ſtick, part of it being under water, as if it were crooked: and two fingers laid croſs one another, repreſent a ſingle bullet roll'd between them, as if there were two; ſo that it is very poſſible, tho' the organ be manifeſtly and vehemently affected by the contact of cold water, yet the cauſe of that impreſſion may, by reaſon, be judged to differ from that which the ſenſe might to an inconſiderate perſon ſuggeſt. We muſt conſider next, that ſenſations may, in ſeveral caſes, be made, as well from alterations happening in the internal parts of the body, as from thoſe which are manifeſtly produced in the external organ, by external objects; as appears by hunger, thirſt, the great coldneſs that hyſterical women complain of, in their head and back, and the troubleſome cold which we every day obſerve, upon the firſt invaſion of the fits of agues. I obſerve then, that tho' in a reſpective ſenſe, the water, wherein the objection ſuppoſes the hand to be plunged, be cold, in regard its parts are leſs agitated than the ſpirits and blood in the hand; yet, in a philoſophical ſenſe, it is not quite deſtitute of heat, ſince it is yet water, not ice, and would not be a liquor, but by reaſon of that various agitation of its minute parts, wherein fluidity conſiſts. Upon account of this reſpective coldneſs of the water, the hand is cooled; for the ſpirits and juices of that organ; meeting in the water with particles much leſs agitated than themſelves, communicate to them ſome part of their own agitation, which they thereby loſe; whence ſuch a change is made in the organ, and in ſome other parts of the body, as is perceived by the mind, under the notion of coldneſs; being, indeed, an internal perception of the change happening in the organ. And if the water, wherein the hand is plunged, comes to be more cooled than before, the ſpirits, blood, and other parts of the hand, finding the aqueous corpuſcles more ſlowly moved than formerly, muſt, according to the laws of motion, transfer to them a greater meaſure of their own motion, and, conſequently, come themſelves to be deprived of it: and upon this increaſe of the ſloweſs of motion in the parts of the hand, there follows a new and proportionable perception of the mind, and ſo a more vehement ſenſation of cold. If then it be remembred, that upon turning one's eye to the dark part of the room, leſs enlightned than the window, tho' darkneſs be but a privation, and tho' the obſcurity of that part be not abſolute, but conſiſts only in a leſs degree

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PHYSICS. of light; yet the action of the spirits, and other parts of the body, is so changed, upon occasion of the light's acting more faintly upon the organ than before, that the pupil is immediately and manifestly dilated; it will be no wonder, that where not only the spirits, but the blood, which circulates thro' the whole body, is disaffected, a great alteration should be felt in the hand, immediately exposed to the action of the cold water.

It might still be urged, that if cold be but a privation of heat, it is a privation of a strange nature; since it may be introduced into bodies, which were not hot before; nay, in some cases, into such as are naturally cold; and, by consequence, must have been put into a preternatural state, to be at any time hot. But since fluidity consists in the various agitation of the insensible corpuscles of a liquor, and heat in a tumultuary, and more vehement agitation of the insensible parts of a body; whence hot water scarce differs otherwise than gradually, from that which is cold to the sense; if cold be philosophically consider'd, it may well be said, that as long as water retains the form of water, and so continues a fluid body, tho' it may be very cold to the touch, yet it is not absolutely or perfectly cold; and, therefore, is capable of a farther degree of coldness, which it receives when brought to congelation; for till then, it was not destitute of those active corpuscles, requisite to keep it fluid; and till then, it was not absolutely or perfectly cold. Nor is it every glaciation itself, which brings liquors to be perfectly cold, in the philosophical sense of the word, so as quite to expel or subdue all the agile particles which were in the water, before it was turn'd into ice. For to effect this change, it is sufficient, that so many of these restless particles be destroyed or disabled, that there remain not enow of them to keep the water in a state of fluidity; so that the surplus may yet continue in the frozen liquor, and whilst there, perform several things; and by their recess, the ice may grow yet more cold. This notion suits very well with the different degrees of hardness observable in different portions of ice, sometimes upon account of the different degrees of cold in the same water or other substance. Thus having put a sealed thermometer into a glass, broader at the top than at the bottom, and oiled the inside, that the ice might not strongly stick to it, we poured in water, more than sufficient to cover the ball of the thermometer; then the water being carefully frozen, we observ'd where the spirit rested; and the instrument and ice being afterwards removed into the open air of a very frosty morning, the ice was taken from the ball; when presently the spirit subsided considerably below the former mark: which proves, that a degree of cold, sufficient to freeze water, may not render a body perfectly cold; this ice itself keeping the included ball warm, by fencing off the air, which at that time was considerably colder than it. And there is no sufficient cause assign'd, why many things, reckoned among privations, or

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negations, by the *Peripatetics*, as cold is by the *Epicureans*, may not admit of degrees no leſs than deafneſs, ignorance, *&c.* Thus in a total eclipſe of the moon, when the earth, interpoſing between the ſun and her, has firſt obſcured her only in part, we generally complain of darkneſs in the air; but when the interpoſed earth proceeds to cover the remaining parts, and ſo makes the eclipſe total, the darkneſs alſo is ſaid to be much increaſed. PHYSICS.

But if it be farther demanded, how a privation, or diminution of motion, can produce the effects we daily ſee produced by cold in the bodies about us; I do not pretend, that either an abſolute privation of motion in a body, or a ſlowneſs of motion in the parts of it, is the proper efficient cauſe of the effects, vulgarly aſcribed to cold alone: for cold is rather the occaſion, than the true efficient of ſuch effects, which are properly aſcribed to thoſe phyſical agents, whoſe operations happen to be otherwiſe modified, than elſe they would have been, upon account of that diminution, or ſlackneſs of agitation, which they meet with in cold bodies; whence they are both themſelves deprived of the agitation they communicate to ſuch ſlow bodies, and thereby act no longer as they would, were it not for that loſs: and by a natural conſequence of this change, which is made in themſelves, they alſo modify the action of other bodies upon them: from which unuſual alterations, happening in a world ſo framed as this of ours, and governed by ſuch laws, with regard to motion and reſt, as are obſerved amongſt bodies; there muſt, in all probability, reſult many new, and ſome of them conſiderable phenomena. For tho' bodies at reſt ſeem to have no action, which among corporeal ſubſtances appears to be performed only by local motion; yet bodies at reſt themſelves, may concur to great effects, both by determining the motions of other bodies, or by receiving their motion totally, or in part, and ſo depriving the moving bodies of it. Thus the arches of a bridge, tho' immoveable themſelves, may, by guiding the water of the river which beats againſt them, occaſion a rapid and boiſterous ſtream, able to drive the greateſt mills, and perform more conſiderable effects, tho' the river, before it met with ſuch obſtacles, ran calmly. And tho' water has its parts in perpetual motion among themſelves, yet ſince that agitation is exceeding ſlow, in compariſon of the ſwiftneſs of a cannon-bullet; ſuch a bullet diſcharged but little above the level of water, often rebounds from the ſurface of it; and, conſequently, from thence receives a new determination. Thus, farther, ſuppoſe upon a ſtream there were built many different mills, and the current was by ſome contrivance diverted another way; muſt not the action of all theſe mills neceſſarily ceaſe too, tho' this change be not produced by any poſitive and direct violence offer'd to the mills, but only by preventing the impulſe, requiſite to keep them in motion? In paralytic affections, where a viſcous humour obſtructs a nerve, tho' its proper and immediate action be only to hinder or weaken the ſpirits, which paſs'd freely

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PHYSICS. along that nerve to the muſcle, whereto it leads; yet the action of the other parts of the body, and the relaxation of the fibres, often produce a tremulous motion in the limbs, and diſtortion of ſeveral parts. But it comes up much nearer to our purpoſe, that animals dye in the exhauſted receiver, merely by a privation of air, in a very few minutes, without the intervention of any poſitive agent. To ſum up the reſult of theſe inſtances, it appears, that the effects undeſervedly aſcribed to cold, need not to be referred to a privation, but to theſe poſitive agents, or active cauſes, which by their own nature are determined to act otherwiſe on, or ſuffer otherwiſe from one another, in caſes where there is a great hinderance, or ceſſation of the uſual motion, than where there is not.

'Tis farther argued againſt us, that ſuppoſing the hand plunged firſt into hot water, and then into cold, why is it not cooled as well in one caſe, as in the other? Is it becauſe the heat of the hand ſhrinks inward in the cold water, and therefore the hand is left leſs hot? But what has heat to fear in the cold water, unleſs it be cold? Now if cold be only a privation, what can it do to heat? A privation is nothing, and therefore cannot affect its motion. This objection, indeed, might puzzle ſome ſchool-philoſophers, but may be thus anſwer'd. When a man puts his hand into warm water, the agitation of the corpuſcles of the liquor ſurpaſſing that of the ſpirits, blood, and other parts of his hand, cannot but excite in him a ſenſe of heat; but when he puts the ſame hand into cold water, the caſe ought to be much altered, not from any imaginary retreat of the ſpirits, but the communication of motion by other parts to the ſurrounding water, by which means there muſt happen in the hand a great decreaſe of the former agitation of its parts; the perception or ſenſe of which decreaſe of motion is that which we call feeling of cold.

There is another argument, drawn from the way of artificially freezing water, by a mixture of ſnow and ſalt, placed about the outſide of the glaſs, containing the liquor; whence 'tis concluded, that, ſince this mixture is thro' the glaſs able to freeze the water into ice, it may as juſtly be affirmed to act by corpuſcles of cold, as fire can be ſaid to act by calorific corpuſcles, when kindled coals, placed on the outſide of the glaſs, make the contained liquor boil. This, indeed, ſeems very plauſable, but not clear and cogent; for it is not ſo evident, that ice and ſalt act by a poſitive quality, as that burning coals do ſo; tho' cold ſeems as well to be produced by the former, as heat by the latter. Innumerable experiments ſhew, that heat is a poſitive quality, conſiſting in a tumultuary and vehement agitation of the minute parts of the body, ſaid to be hot, and producing alſo in the bodies, whereto it is communicated, a local motion, which is manifeſtly a poſitive thing; and by the confeſſion of nature herſelf, in many inſtances, heat is a poſitive quality: but that cold is ſo, doth not appear even by artificial conge-

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ſoon afrer, this water begins to turn into ice; but that this glaciation is performed by ſwarms of atoms of cold, which permeating the glaſs, invade and harden the liquor, is not perceived by ſenſe, but concluded from reaſon. So that if another intelligible way can be propoſed, fairly to explain the phenomenon, beſides that, the objection drawn from this experiment againſt my hypotheſis, will be invalid. And ſuch an explanation M. *Des-Cartes* affords us: the ſubtile matter, ſays he, which ſurrounds this water, being more groſs, and conſequently more forcible than that which ſtuck about the parts of the ſnow, poſſeſſes its place, whilſt the parts of the ſnow roll about the parts of the ſalt in the act of diſſolution; for it moves more eaſily thro' the pores of ſalt water than of freſh, conſtantly endeavouring to paſs from one body to another, in order to come where its motion may be the leaſt reſiſted; whence the more ſubtile matter goes from the ſnow into the water, to ſucceed that which went out there; and being unable to continue the agitation of water, ſuffers it to congeal. And this bears analogy to the practice of drying precipitates upon brown paper, or pieces of brick, or chalk; which haſten the exſiccation of the things laid upon them, not by any drying particles they emit into the ſoft ſubſtances, but by imbibing the ſuperfluous parts of the liquor of the ſubſtances to be dried. Thus I have immerſed a piece of ſoft bread into an actually cold liquor, that would haſtily imbibe its aqueous corpuſcles, and dry it, in a minute or two, ſo as to make it feel hard. And by putting into weak ſpirit of wine a ſufficient quantity of ſalt of tartar, the ſpirit will be dephlegmed without diſtillation, or ſo much as heat; which the better illuſtrates the *Carteſian* explanation; becauſe, by the change made of the greater part of the ſalt of tartar into a liquor, which will not mix with the ſpirit of wine thus rectified, it is manifeſt, that the aqueous particles of the weak ſpirit, more readily continuing their motion among the fixed corpuſcles of the ſalt, than the vinous ones of the ſpirit, they paſs into the alkali, and diſſolve it; and thereby deſert the liquor, thro' which they were before diffuſed. And there is another ſaline body, which ſo unites with water, as not to be, by the eye, diſtinguiſhed from it, yet it is of ſuch a texture, that water will forſake this body it kept in agitation, to paſs into ſpirit of wine, and ſo leave that, which it kept in the form of a liquor before, to appear in the form of a conſiſtent body; which comes nearer the propoſed experiment of glaciation. But this is yet farther illuſtrated by the fuſion of camphire into a liquid, with the ſteam only of *Aqua fortis*, or ſpirit of nitre, and the recovery of its conſiſtence, by pouring common water to it; for that theſe ſpirits are not ſenſibly warm (no more than the *Carteſian materia cœleſtis*) in water,

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PHYSICS. water, is manifeſt to the touch. And tho' I at firſt ſuſpected, that the reaſon why pouring this oil into water, preſently reduces it to camphire again, might be the coldneſs of the water; I afterwards found it rather owing to the nitrous ſpirits being diſpoſed to paſs out of the oil into the water, whilſt the liquor readily imbibed and diluted them, and conſequently diſabled ſo many of them, that thoſe which remained, could not any longer perform their office; ſince the reduction of the oil into camphire would preſently be made, tho' that liquor were not poured into cold water but hot: ſo that the agitation, which it received from the particles of the menſtruum, tho' not to the touch ſenſibly warm, was much more efficacious, than that it received from the heat of the water. There may alſo be corpuſcles of ſuch a nature, in their ſize, ſhape, and other attributes, as to be fit to enter the pores, and pierce even into the inward parts of water, and ſome other bodies, ſo as to expel the calorific corpuſcles they chance to meet with, or to clog, or hinder their activity, or, on ſome other account, conſiderably leſſen that agitation of the minute parts, by which the fluidity of liquors, and the warmth of other bodies is maintained. But, even in ſuch caſes, tho' the agent and the actions, which produce coldneſs, are poſitive things; yet the nature of coldneſs itſelf may conſiſt in a privation. Thus, when a man is killed by a bullet, his death is effected by a poſitive, and even impetuous action; yet death itſelf is but a privation of life. If alſo in a dark room, a man caſt cold water upon a burning coal; tho' the water acts by its poſitive quality of moiſture, and, by virtue of that, extinguiſhes the fire, and ſo deſtroys the light; yet the darkneſs, conſequent upon this action, is not a poſitive thing, but a privation.

The laſt argument that remains to be conſider'd is this. Tho' many things ſeem to grow cold upon the bare abſence of heat, yet unleſs an external cold be introduced into them, they do not ſo properly grow cold, as loſe a degree of heat. Thus a ſtone, or a piece of wood, which we ſuppoſe neither cold nor hot, will become hot when applied to the fire; but when that heat ceaſes, and nothing cold is near them, we may properly ſay they are become leſs hot, and return to their own ſtate, not that they grow cold. But this ſeems to be a diſpute about words. If we ſpeak only of a coldneſs as to ſenſe, I ſee not why any body, that is heated by the fire, may not upon its removal thence be ſaid to grow cold, and not barely to loſe its heat. For the ſenſible coldneſs of water, conſiſting in a diminution of the motion of its corpuſcles, that ceaſe to be as much agitated, as thoſe of our organs of feeling; if this impaired agitation be ſtill more leſſened, the liquor will ſtill grow colder, without the help of any poſitive cauſe, till at length the agile parts, which kept it fluid, being quite expelled or diſabled, the form of the liquor comes to be exchanged for that of ice. To that part of the argument, which propoſes an indifferent

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were cold by an agent, positively and actively cold; we reply, that it is one thing to propose such a neutral body, as a possible thing; and another to give instances of it, in particular bodies, wherein that neutrality is not to be found. But if a body should be proposed as adiaphorous with regard to heat and cold, I might say, that if such an one should be carried into a hot place, it might there grow warm; and if removed back again, and kept till it lost that new adventitious heat, it might rather be said to lose its heat, than grow cold, as to sense. The reason is, because every diminution of heat, cannot denominate a body cold, but only such a degree as reduces the parts of it to a fainter motion, than is at that time in those of our organs of feeling; and till this is done, the body proposed is still in a state of heat, as to sense; tho' in regard of other bodies, it may then be naturally cold. Thus lead, which hath but heat enough to keep it in fusion, may, by the pouring on of such water, as to a man's hand would feel hot, be brought to grow hard; which loss of fluidity is also the natural effect of cold, tho' perhaps both the metal and the liquor be yet, as to sense, considerably hot. So that this controversy seems to be rather verbal than real, and may be determined by settling the distinct acceptation of the words cold and heat.

But notwithstanding these answers to the arguments, all of them alledged by the learned *Gassendus*, many difficulties remain with me, particularly as to the production of cold, by corpuscles of cold. I shou'd be gladly satisfied whether, and on what account, those little fragments of matter are cold? Whether those frigorific particles, which must in multitudes crowd into water, to turn it into ice, have gravity or levity, or are indifferent to both? What structure the corpuscles of cold are of, to make them frigorific to that innumerable variety of bodies, they are said to pervade? Whether the frigorific faculty of these corpuscles may be lost or not? Whether they are primitive bodies; and if not, whether there was no cold in the world, before they were produced; and whence that cold could proceed? And lastly, if they are said to be primitive bodies, how it comes to pass, that by putting a certain factitious body actually warm, into water, which was also warm, there should presently ensue an actual coldness?

But there are two grand problems relating to this subject, which I require to be solved. The first is, how, upon the mixture of two or three bodies, there should manifestly ensue a great and tumultuary agitation of small parts, yet even during this conflict, not any sensible heat, but a considerable degree of cold be produced, and that even in the internal parts of the mixture? This might tempt one to ask, whether

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PHYSICS. ther local motion is, in its own nature, a generical thing, which may be ſo diverſified by circumſtances, that one kind of modification of it, as it is made in corpuſcles of ſeveral ſizes and ſhapes, may be the cauſe of heat, and another that of cold. What gives riſe to this problem is, the following experiment. We took two or three ſaline bodies, each of them purified by the fire, and mixing them together in a due proportion, they produced what to the eye appear'd a great efferveſcence; but tho' the hiſſing noiſe were laid, and the numerous bubbles ſuddenly generated made the matter apt to over-flow the glaſs, if ſmall, or the ingredients haſtily put in; yet even whilſt this ebullition laſted, the containing glaſs felt extremely cold; ſo that even in winter, the outſide of it wou'd be quickly cover'd with large drops of dew, gain'd from the external air, which afterwards uniting, trickled down by their own weight: and by gradually throwing more of the ingredients upon each other, we cou'd prolong the experiment at pleaſure, and that at various ſeaſons of the year. And once taking two deep glaſſes, I put a quantity of fair water, of the ſame temper with the ingredients, in the one, and ſome of our ſaline mixture into the other; and letting down a thermometer into the water, to acquire the temper thereof, I raiſed it up by its ſtring, and placed it in the mixture that was then hiſſing, and filling its containing veſſel with bubbles, upon which the tinged ſpirit ſubſided from four inches ½, to 1 ½ inch. Then removing the thermometer into the common water again, the ſpirit ſoon mounted to above 4 ½ inches. And this I twice repeated with the like ſucceſs. So that the coldneſs of this mixture, was far from being a deception of the ſenſe. And to ſhew how much this ſtrange coldneſs depends upon the peculiar texture of the mixture, or of its component particles; I took the remaining part of the acid liquor that went to compoſe the mixture, and put thereto a convenient quantity of fair water of the ſame temper; but they ſcarce, upon this, ſenſibly differ'd in coldneſs, when examin'd by a good ſealed thermometer. Some of the pure ſalt, alſo, uſed in the mixture, being added to water in the like manner, gave no manifeſt ſigns of an encreaſed coldneſs; no more than the glaſs wherein I uſually kept a large quantity of our ſalt: whence the coldneſs of the mixture cannot be attributed to either of the ingredients apart, but is a quality ariſing from their union. And when I had left ſome of this mixture for a night, in the ſame room with a glaſs of fair water, and a good ſealed weather-glaſs; I cou'd not in the following morning, when the tumult of the contrary ſalts of the mixture was ceaſed, perceive any conſiderable difference betwixt the coldneſs of that, and of the water. And having, inſtead of the ſalt I hitherto employ'd, mix'd ſome of the very ſtrong ſpirit of this ſalt, and which uſed to come over therewith in diſtillation, with a ſpirit drawn for the purpoſe, which ſeem'd exactly like the other I had alſo hitherto uſed, being made wholly

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he ſame manner, the mixture of theſe two, inſtead of growing hot, PHYSICS.
ame warm, and ſuddenly impell'd the ſpirit in the thermometer,
n three inches to above eight. And the like contingency I have
other times found in making the experiment. On the other hand,
ingredients uſed herein, wou'd produce a manifeſt coldneſs, tho'
ſalt were firſt well warmed by the fire. The way of preparing
ſe liquors and ſalts, I am obliged to conceal; but to ſhew the
ne phenomena in a leſs degree, I put to very good ſalt of tartar,
convenient quantity of the ſpirit of vinegar, tho' I am not ſure that
is will always ſucceed.

My ſecond problem is this, From whence proceeds the vaſt force
freezing water? For, reſiſting bodies being to be broke by a
olent local motion, and cold either conſiſting in, or at leaſt being
companied with a privation, or a great diminution of motion;
ſeems very difficult to conceive, how it ſhould make water ex-
rt ſo wonderful a force. *Gaſſendus* indeed teaches, that glaciation
perform'd by the entring of ſwarms of corpuſcles of cold into
he liquor; but I much doubt this ſolution: ſince theſe atoms of
old ſeem not to make that expanſion of the water required; for
hough water will be more refrigerated, as the air grows colder,
et till it be brought to an actual glaciation, all the ſwarms of the
frigorific atoms in it, are ſo far from expanding it, that they more
and more condenſe it. And even that degree of cold, which deſtroys
fluidity, tho' it expands water, does not do it merely by the multi-
tude of the frigorific corpuſcles, which invade the pores of the fluid
body; ſince pure ſpirit of wine, and almoſt all chymical oils, tho' ex-
poſed to the ſame degree of cold, that turns water into ice; and, as
I have tried, to a far greater degree, than is neceſſary for that pur-
poſe; will be the more condenſed by thoſe ſwarms of particles. But,
what is more conſiderable, I have carefully obſerved, that, beſides
common or expreſs'd oils, chymical oil of aniſeeds itſelf, being fro-
zen by an intenſe degree of cold, will not be expanded, but greatly
condenſed, and accordingly grow ſpecifically heavier than before. But
no liquor beſides water will ſwell with cold; nor will water itſelf do ſo
upon every degree of cold, but only upon ſo great a one, as actually
turns it into ice: and upon the freezing of water, we may obſerve in
the ice many bubbles, ſuppoſed to be aerial, intercepted between the
ſolid parts: which ſuppoſition, if true, would perhaps raiſe a ſuſpi-
cion, that the air contained in theſe bubbles might have an intereſt
in the phenomenon; ſince I have found by trials, purpoſely made, that
air gather'd into viſible portions, may exerciſe a conſiderable elaſti-
city, that appeared not, whilſt it was inviſibly diſperſed in the wa-
ter. To demonſtrate, that freezing water has actually an expanſive
force, we ſhall here add an experiment of the ſame nature, with ſome
formerly mention'd to the like purpoſe; and more fully repeat two or
three others, which were made to meaſure this force.

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The expanſive force of freezing water demonſtrated, and eſtimated.

And firſt, I cauſed the barrel of a ſhort gun to have a ſcrew fitted to the mouth of it, by which we might eaſily ſtop it, as we did the touch-hole after another manner; then filling the barrel with common water, and exactly cloſing it with the help of the ſcrew, we laid it in a convenient veſſel, where 'twas encompaſſed with a frigorific mixture of ſnow or ice, and ſalt; and in a ſhort time we found the barrel burſt; part of the ice appearing along the gaping crack, made in the body of the iron by the freezing water. But to meaſure this expanſive force,

2. We took a ſtrong cylinder of braſs, its cavity two inches in diameter; into this was put a bladder of a convenient ſize, containing a quantity of water, ſo that the neck of it being ſtrongly tied, the water might not get out into the cavity of the cylinder, nor be able to expand otherwiſe than upwards. Into this cylinder we fitted a wooden plug, turned on purpoſe, which was ſomewhat leſs in diameter than the cylindrical cavity, that it might riſe and fall eaſily in it. Upon the upper part of this plug was laid a conveniently-ſhaped flat body, whereon were placed ſeveral weights to depreſs, and hinder its riſing by the expanſion; then a frigorific mixture being applied to the cylinder, it appeared, within about half an hour's time, (by a circle, which had been purpoſely traced on the ſide of the plug, where it was almoſt contiguous to the orifice of the cylinder,) that the water in the bladder began to expand itſelf; and in two hours after, the circle appeared to have been raiſed near half an inch, notwithſtanding one hundred and fifteen pound weight, that endeavoured to hinder the aſcent.

3. At another time uſing the like apparatus, the cylinder being $3\frac{8}{10}$ inches in diameter, and in depth four inches, we took out the bladder, and found the cylinder of water within it not wholly frozen, ſome liquid parts appearing about the centre; which liquor, if we had not too ſoon deſiſted from the experiment, might probably have raiſed the weights ſomewhat higher. The ice here being in length but three inches, and $\frac{1}{2}$; yet ſo ſmall a quantity ſufficed to raiſe, beſides the board whereon it reſted, an hundred pound weight *Averdupoize*.

4. We repeated this experiment, and now the plug raiſed two hundred and fifty four pound weight.

The End of the Firſt Volume.

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